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ABSTRACT

The report details the results of a research and development program on communication aids for the education of the non-vocal severely handicapped. Much of the information in the report was prepared so that it could stand alone, and is in the form of individual papers, reports, and a sourcebook. The documents are divided into three sections: (1) "Review of the Problem and Past Work by the Field", (2) "Overview of Grant Activities" including background information, objectives, notes on implementation, and major results on seven projects (Formative Evaluation/Design of a Low-Cost Scanning Aid, Development of Universal Control Module Based Communication Aids, Switch Set Studies, Voice Synthesizer, Case Study Evaluation Program, Developing and Implementing a Comprehensive Study of Communication Aids as They Affect Education and Communication Skills of Non-Verbal Motor Impaired Children, and Preliminary Language Study Probes); and (3) "Project Documentation" (about two-thirds of the report). (Author/PHR)

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ED163678

FINAL REPORT

COMPREHENSIVE AND DEVELOPMENT OF COMMUNICATION AIDS AS AIDS TO THE EDUCATION OF THE NON-VOCAL SEVERELY HANDICAPPED

BEH/OE OEG-0-74-7461

September 1, 1974 to March 1, 1976

BEST COPY AVAILABLE

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U S DEPARTMENT OF HEALTH,
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INTRODUCTORY REMARKS

This report describes the major results during the period of 9/1/74 to 3/1/76 under Grant #OEG-0-74-7461 from the Bureau for the Education of the Handicapped, Offices of Education HEW. This grant covered several aspects of a more comprehensive program which included research integration, information dissemination, training, communication aid research and development and evaluation. A brief overview of the program of which this grant was a part is described briefly at the beginning of Section II of this report.

The report itself has been divided into three sections. Since this is the first major program report to the Bureau, Section I has been set up to present an overview of the problem being addressed and the research that had been done by others leading up to this program. Section II provides an overview of the grant activities along with a summary of each of the project areas. Included in these brief summaries are background information, objectives, notes on implementation of the projects and a brief discussion of the major results.

Since this program was a research and development program and not a research program, the principal results of the program are intended to be or to lead to teachers/clinicians usable materials of information. In order to maximize the useful dissemination of the documentation of this program, much of the project documentation in this report was prepared such that it could stand on its own outside of the report. Thus, much of the documentation takes the form of individual papers, reports or, in one case, a sourcebook. These documents are being made available both together in this report and separately through publication, information centers and direct dissemination from the Trace Center. The major documents of this type are contained in Section II of this report and form the bulk of the documentation on the individual projects.

SECTION I

REVIEW OF THE PROBLEM AND PAST WORK BY THE FIELD

A. THE PROBLEM

With recent legislation and increased emphasis in appropriate educational and pre-educational programs for severely handicapped children, many severely multiply handicapped children are being brought into better, more appropriate and less restrictive educational environments. This integration,however, has caused new problems for clinicians and special education teachers many of whom have not previously worked with severely physically handicapped children. Some of these children present combinations of problems which make it particularly hard to develop programs for them or to incorporate them into educational situations. In the instance of non-vocal, severely handicapped children (NVSPH) the clinician/teacher is frequently presented with a student of normal or near-normal intelligence who is non-vocal, non-manipulatory, non-ambulatory, and who, therefore, has little or no means of interacting or participating in educational or other types of programs.

Of primary concern in the development of programs for these children is their lack of effective means to communicate due to their physical inability to use speech or gesture. Because of the essential nature of communication both to development and to everyday life, much of the effort for these NVSPH individuals has been turned toward developing effective means of communication. In those cases where speech is not possible or where it will be severely delayed, augmentative or supplementary modes of communication are being explored and implemented to help meet their communication needs. Manual techniques, communication boards and other communication aids have been and are being developed to help meet the communication needs of these individuals. The diversity of the handicaps possessed by NVSPH children, however, and the fundamental role which communication in general plays in the personal development of any individual put a large demand, as well as a large number of constraints upon the communication aids and the communication development programs for these children. To examine some of the communication needs of the developing NVSPH child, a review of the child during three periods of his life will be made. Although these reviews do not cover all of the communication needs of an individual, or of a physically handicapped individual, they do provide a fairly good picture of the magnitude of the problem we are trying to solve when we attempt to compensate for some of the severe handicaps to communication interaction and development of the NVSPH child.

COMMUNICATION DURING THE PRE-SCHOOL PERIOD

During the period from birth to the time a child enters a formal educational program, the typical child's development can be characterized as orienting, exploratory and interactive. The non-manipulative non-ambulatory child, however, is unable to participate in many "typical" infant exploratory activities. He is generally unable to move himself about in his environment even when he is well beyond infancy. When objects are close at hand he may be unable to grasp and explore them. For severely physically handicapped children, the primary mechanism for exploration and learning must, therefore, be through questioning or through directing the actions of others. Normal, vocal children rely heavily on these techniques as evidenced by the plethora of questions generally typical of young children. Yet this type of exploration is impossible for the non-communicating child.

By the same token, a large percentage of the child's personality development also takes place during these years - principally through interaction with others. For the non-communicative, non-manipulative child, interaction usually remains on the infant level even as they reach age four to five and personality, as it usually would be defined in the vocal child, is generally not developed. Often, the NVPH child's behavior may be typified by stubbornness and other similar efforts by the child to exert some control over his environment by passive-aggression, since he is constantly frustrated in his attempts at direct action due to his severe physical handicap.

Other fundamental developmental achievements may also be missed by the NVPH child if he remains non-communicative through this period. When educational programs are finally offered to this child, he will most likely be unprepared cognitively, emotionally, and developmentally. In addition, he will have few readiness skills for the communication and interaction necessary in the educational process.

Non-vocal communication intervention in the child's early years can help to compensate for many of the developmental barriers which the child faces. Through aids and techniques, children can begin to interact with and control their environment. Through communication, they can ask questions and can elicit responses and action from people in their environment. That which they learn about but cannot directly experience can be explored through interactions with others. Personality development can be facilitated and communication skills can be developed which will enable the child to interact with others and enter into more appropriate educational programs when the time comes. In addition, he will understand the meaning and power of communication.

The constraints and requirements for communication aids in this period of the child's life are more restrictive than for any other period. During this period, the child's physical abilities will not be well developed; thus, many of the more efficient techniques which require fine motor control may not be initially applicable. Initial techniques used at this time must be extremely simple and straightforward. They must be able to be used with pictures, symbols, and possibly actual objects and must be able to change easily to allow for development commensurate with the maturation of the child's physical and communication skills.

COMMUNICATION AND THE CLASSROOM

In discussing communication and the classroom, it is important to consider the very fundamental role that communication plays in the educational process. Consider for a moment the operation of a typical classroom. The teacher interacts with the class; the students question and respond; the teacher writes on the board; the students copy assignments, complete written exercises, and do independent work. Whenever the lesson or assignment becomes confusing, the child can raise his hand and ask a question. Interaction is used as the basis for information transfer.

For a child with normal and adequate modes of communication, this illustration is typical of his educational routine. But the non-vocal severely handicapped child is unable to speak, use a pencil to complete written assignments or even raise his hand and ask a question. Unable to respond, he cannot participate in class discussions. Unable to write, he cannot provide the teacher with feedback that is necessary for demonstrating understanding or measuring learning.

Perhaps even more important than feedback to the teacher, is the child's inability to generate feedback for himself. If he cannot speak or write, he has only limited means to rehearse ideas and thoughts. If he cannot write, he has no means to complete tests and assignments, do homework, develop his writing and math skills or log down thoughts, observations or impressions of the world around him. Unable to question (through vocal or written means), much knowledge may be lost in the wake of confusion or simple misunderstanding. Thus, the efficiency of his educational program is directly related to the efficiency of his ability to communicate.

Recognizing this, many educators have affirmed that the child who cannot transmit information effectively is at a severe disadvantage in any educational setting, even classroom situations especially designed to handle physically handicapped children.

Besides the physical constraints which restrict his communication, the organization of the classroom itself may pose additional limitations to the NVPH child. Since this child is often placed within a group of students who are able to communicate effectively through normal methods, the teacher faces the frustrating task of deciding which programs will meet the needs of the majority of her students. The attentional demands of the non-vocal severely handicapped child may preclude total integration with vocal children in a group interaction. If the handicapped child wishes to respond in a class discussion, the teacher must divert her attention from the group and concentrate on the NVPH child for the several minutes it would take the child to laboriously express his thoughts. During the time, the other children may become restless and inattentive, and the teacher would have to restore control before continuing. Thus, in order for the child to participate, he must disrupt. The child placed in a group situation may therefore be placed in a position of passive observation. Yet active participation is an essential aspect of the learning process.

Another important facet of the classroom routine is independent study, a time to explore subjects of interest and expand knowledge and experience aside from the efforts of the teacher. Through independent learning experiences, a child is able to develop self-confidence and discover success and fun in learning. These experiences are, for the most part, denied to the handicapped child who must rely on the availability of a second person to do his "independent" work.

It can be seen that when a NVPH child moves into the classroom situation, his communication needs increase. If the child has the potential to acquire a sight word vocabulary or to spell, he may need an "independent" aid (i.e., an aid which has some kind of printer in it). This aid can provide him with a means of communication/writing by which his full potential can be realized. Providing the NVPH child with an aid that prints out the message as the child contructs it (thus, making him independent of another's help) may allow placement of the NVPH child in a much more appropriate and effective learning situation. Such an aid would require of the teacher only the time that it would take to read the message. Further, the aid would allow independent work on the part of the NVPH child which would greatly increase his ability to benefit from educational programs. Thus, an "independent" aid can increase an NVPH child's active learning time and at the same time, reduce very expensive one-to-one assistance time of the teacher. Because of these gains, even the cost of a relatively expensive communication aid can be justified in a short period of time.*

For children who will not be able to learn to use words to communicate, "independent" aids may not be the most appropriate. The communication needs of these children, however, are just as great, and approaches are available using pictures or symbols to provide them with an effective means to express themselves and to interact with those in their educational environment.

COMMUNICATION BEYOND THE CLASSROOM

Once an individual leaves the classroom, his communication needs may again change. Because of severe manipulative handicaps, many of these individuals may be better suited to jobs which can take advantage of their non-manual skills. If they are able to secure jobs, the ability to communicate and produce written output efficiently will be extremely important. In addition, they may be required to operate devices such as calculators, business machines, or computer terminals. Unless these individuals are able to operate these aids by manual skill, their communication aid may be called upon to provide them with an efficient means of controlling these devices as well. Thus an aid will have to be very flexible and allow for control of external devices in order to meet the vocational or career needs of a NVPH individual.

There will also be those who are unable to secure employment. For them, the ability to interact with others and to control basic functions in their environment will be of great importance. In this situation, effective communication may be of more importance than any other benefit of their educational programs. The types of aids which will best fit their needs will vary widely, depending on the individual's mobility, physical abilities, and communication level. Appropriate aids may range from basic communication boards to independent aids capable also of controlling certain appliances in their environment.

SUMMARY OF NEEDS

It can be seen that there is a need for aids on different levels of function, ranging from fundamental aids, such as the communication board, to "independent" aids. Of prime importance are the fundamental techniques and aids--aids which can provide basic communication ability to the child who is just developing communication. In some cases, aids which can provide more functions are needed: aids which can provide a child with a portable, independent means of communication and writing. In addition, different types of aids are needed to accommodate the different types and degrees of physical ability which these children have. To meet these needs, clinicians and researchers have developed a variety of techniques and aids to facilitate non-vocal communication.

B. REVIEW OF BASIC APPROACHES TO PROVIDING A MEANS OF INDICATION TO FACILITATE COMMUNICATION FOR THE NVPH CHILD

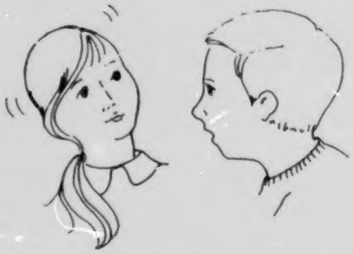
Although a great many different techniques have been developed to provide the NVPH child with a means of indicating the elements of his message, the techniques are all essentially variations on three basic approaches. These approaches are scanning, encoding, and direct selection. This section describes these three methods and provides examples for each type. It also explores the range of complexity of these techniques and their implementation from fundamental communication aids to more advanced communication systems.

SCANNING COMMUNICATION AIDS

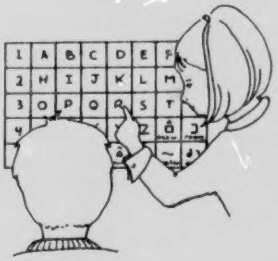
The formal definition of scanning aids which has been developed by the Trace Center is:

> Any technique or aid in which the selections are offered to the user by a person or a display, and the user selects the message elements by responding to the person or display. Depending on the aid, the user may respond by simply signalling when he sees the right choice presented, or by actively directing an indicator (e.g., light or arrow) toward the desired choice. (Vanderheiden, Harris-Vanderheiden, 1976).

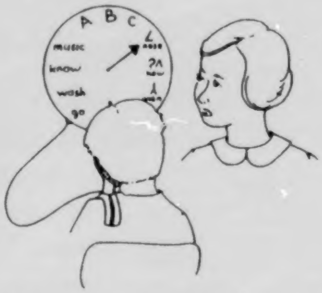
In more general terms, a technique is considered a scanning technique if the choices the child has (e.g., pictures, symbols, words, etc.) are presented to him one at a time so that he can indicate that item he wants by signalling while it is being presented. The simplest example of a scanning technique is the familiar "yes/no" guessing technique. Here the person trying to communicate with the child presents the child with choices, one at a time, and the child nods or signals "yes" when (and if) the second person reaches the desired message (Figure 1A). To add reliability to this technique or to facilitate the use of the technique with the alphabet, a letterboard or pictureboard may be used to present the choices to the child. Here again a second person would scan over the choices, watching for a signal from the child (Figure 1B). As can be seen, this technique requires very little physical skill on the part of the child; he need only be able to make some unambiguous movement to act as a signal of affirmation.



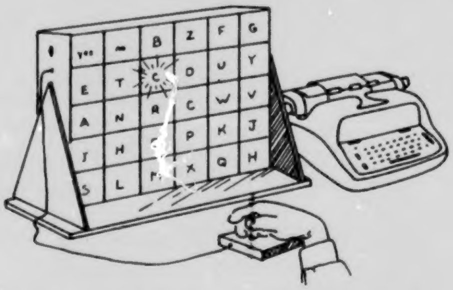
A. Yes/No Guessing



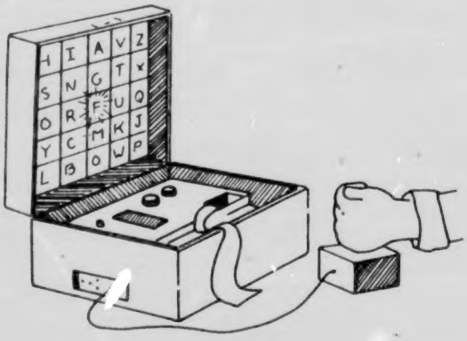
B. Manual Scanning of Communication Board



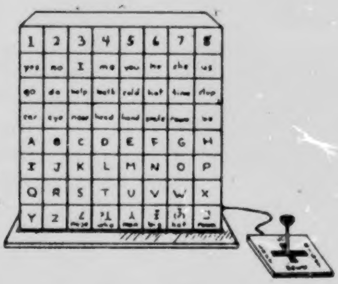
C. Rotating Pointer Communication Aid



D. Printing Communication Aid Using Row-Column Scanning



E. Portable Printing Communication Aid



F. Directed Scan Communication Aid

FIGURE 1 SCANNING TECHNIQUES AND AIDS

These techniques are time-consuming, however, and require the constant attention of a second person.

To lessen the effort required by the second person and to provide the child with more control, simple electronic or electromechanical aids can be used to implement the scanning approach. Figure 1C shows a child using a rotating pointer which he can start and stop by using head movements. Again, pictures, symbols, words, or letters can be used to match the abilities of the child and different switches could be used with the aid for children having better control over different movements.

The need for constant and undivided attention by a second person can be completely eliminated if the child is using an aid which provides him with the ability to print out his message independently. Figure 1D shows an aid which uses the scanning technique and controls a typewriter. With this aid, the child could prepare his message and then call the attention of the second person. The second person would only need to direct his attention to the work for the brief period of time necessary to heed the message instead of having to concentrate on the child's communication during the entire period needed to construct the message. With such an aid, a child would be able to participate in group discussions or interactions without having to monopolize the time of the person(s) with whom he is communicating. This type of aid also allows the child to do independent work, homework and class assignments for schools, or to do creative work or letter writing.

Because the ability to communicate without requiring large amounts of a second person's time can greatly increase the child's communication opportunities, it is of great advantage to the child if his communication aid is portable. This is a problem which is usually not encountered with the simpler aids, but is a problem with aids designed to control typewriters. Special aids have, therefore, been designed which can print out (or display) the child's message and yet be compact enough to move around with the child in his wheelchair (Figure 1E).

Because speed is so important in communication, several techniques have been developed to increase the speed of the scanning approach. Some of these are: two-speed scanning, directed scanning, row-column scanning, and, most recently, predictive scanning.

Two-speed scanning aids increase the speed of selecting an item by providing the child with a second switch he can use to increase the scanning speed when the item he wants is further down the line. With this aid, a child holds down the "fast" button until the indicator gets near the item he wants. The child then releases the button, letting the aid approach the item at the slower scan rate. Finally, the child hits the first button to stop the indicator on the desired item.

With the "directed scanning" technique, the child can control the direction that a person or aid scans, as well as being able to stop the aid when it is displaying his desired choice. Figure 1E shows an example of a directed scanning aid. Here the child controls a joystick which can be pushed in one of four directions to make the lighted square move up, down, left, or right. Using this aid, the child is able to move the indicator light directly to the square he wants and stop it there.

Perhaps the most common scanning technique is the row-column scan. Here the aid (or a second person if a technique similar to Figure 1B is used) indicates or lights up an entire row at a time until the child signals that the square or letter he wants is in the indicated row. The aid (or person) then lights up (or points to) the individual items in that row until the child signals again. Using this technique, it would take an average of only eight steps to pick out one time from sixty-four, whereas, it would take an average of thirty-two steps if each item were indicated one at a time until the child signalled. This technique can be made even more efficient by putting the most common letters or words in the upper corner where they are the first to be presented to the child.

The latest technique to be developed uses an aid which is able to "look at" the last letters printed by the child and predict what the next letter will probably be. It then displays first those letters which are the most probable, to allow the child quick access to them. For example, if the last two letters printed by the handicapped person were "...th," the aid would present the letters E, A, (space), I, first. Using this system, the probability is 81.3% that the letter the child wants will be one of the first six letters presented by the aid. This compares with a 56% probability that the correct letter would be among the first six letters if a fixed sequence of letters were chosen based upon letter use frequencies (e.g., the fixed sequence, (space), E, T, A, I, O), (Foulds, 1974).

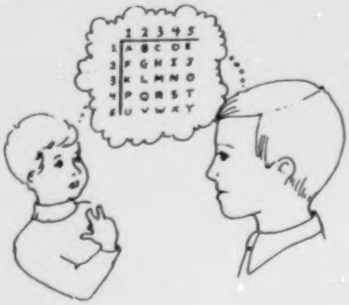
ENCODING COMMUNICATION AIDS

The formal definition for encoding aids is:

> Any technique or aid in which the desired character is indicated by a pattern or code of input signals and where the character codes must be memorized or referred to on a chart (Vanderheiden, Harris-Vanderheiden, 1976).

When an aid is used, any number of switches may be used (e.g., 1, 2, 7, etc.). The code may involve activating the switch(es) sequentially, simultaneously, or in a specific time sequence.

One very simple example of an encoding technique is to envision the letters of the alphabet (Z excluded) in a five-row x five-column matrix. (Figure 2A). Any letter in this matrix can be reached (indicated) by a sequence of two numbers: the first number would index which of the five horizontal rows was chosen; the second number would index which of the five columns contained the letter choice. For example, (see Figure 2A) to select the letter H, a child would hold up two fingers, indicating Row 2; then he would hold up three fingers indicating Column 3 -- thus, the letter H. This same approach could be used with a less dexterous child by having the child point to numbers on a number line. Pictures, symbols, words, or letters could be arranged on a card with number pairs beside each. The child can direct a second person's attention to any item by pointing to the two numbers on his number line corresponding to the number pair beside the desired item. In this manner, a child who is able to point to only a small number of items reliably would be able to indicate any one of a large number of items on the chart by encoding. For children too young to use the number pair technique, colors can be used in conjunction with the numbers in a color-number encoding technique. With this method, the chart would be separated into eight (or any number) sections - each of a different color. Eight pictures, symbols, etc., would be placed within each section next to a single number. The child would then indicate his choice by indicating the color of the section his choice was in and then the number that was next to his choice.


1 2 3 4 5
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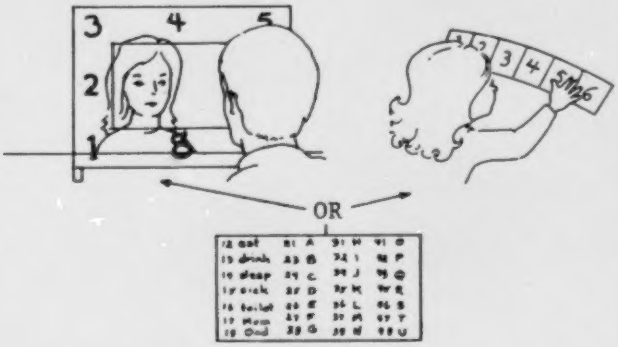
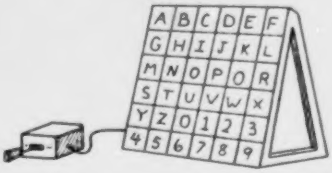
4 P Q R S T
5 U V W X Y

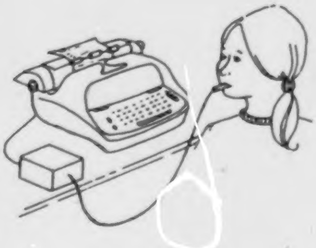
A. Unaided Encoding Technique


3
4
5
2
1
8
1 2 3 4 5 6
OR

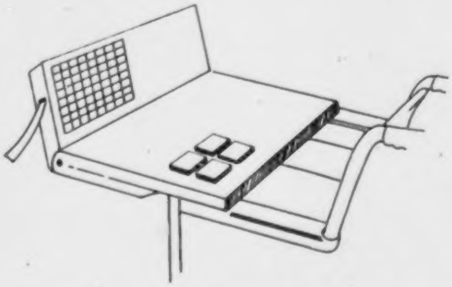
B. Two-Movement Encoding Technique


A B C D E F
G H I J K L
M N O P Q R
S T U V W X
Y Z 0 1 2 3
4 5 6 7 8 9

C. Morse Code Decoder Display Communication Aid



D. Sip and Puff Encoding Communication Aid



E. Portable Printing Encoding Communication Aid

FIGURE 2 ENCODING TECHNIQUES AND AIDS

For the child who cannot point but who does have control over his eyes, the above encoding techniques can be implemented using the child's eye gaze. One method of doing this involves the use of a clear plexiglas panel with the numerals on it called an ETRAN-number system (Figure 2B). The child communicates by looking at the numbers (or color and number) to indicate the elements of his message on the listing. For advanced children, the letters of the alphabet can be put directly on the plexiglas sheet and a more sophisticated coding system used.

Aids can be used to make encoding systems easier to use by decoding the child's movements for the second person and directly displaying the child's choice. An aid could, for instance, decode a child's Morse Code and directly display the appropriate letter (Figure 2C).

As with the scanning approach, encoding aids exist which can provide the child with a completely independent means of writing in either a stationary form (Figure 2D) or a portable form (Figure 2E).

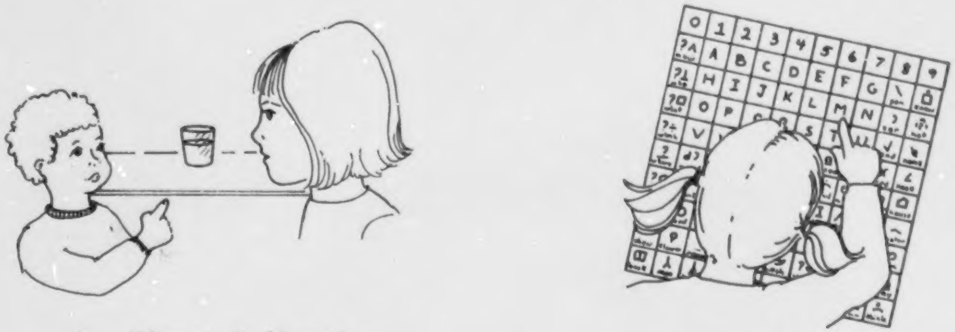
DIRECT SELECTION COMMUNICATION AIDS

A direct selection technique is:

> Any technique (or aid) in which the desired output is directly indicated by the user. In direct selection aids, there is a key or sensor for each possible output selection. (Vanderheiden, Harris-Vanderheiden, 1976).

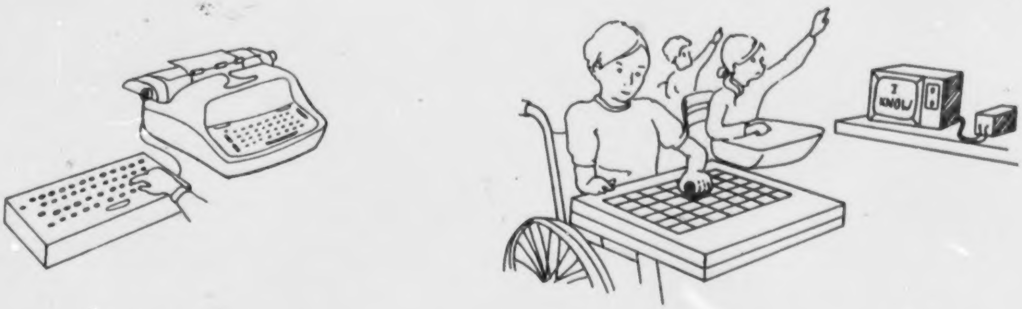
The direct selection approach is the most straightforward and common of the three approaches. The simplest example would be a child pointing directly to an object to convey a message (e.g., to a glass when he wants a drink, to the toilet when he wants to use the toilet, etc.) (Figure 3A).

Another very simple and familiar aid of this type is the letterboard or communication board. With this method, the person points directly to



A. Direct Indication

B. Pointing Communication Board



C. Masked or Guarded Keyboard

D. Auto-Monitoring Communication Board

FIGURE 3 DIRECT SELECTION TECHNIQUES AND AIDS

the various pictures, symbols, words, or letters that make up his message (Figure 3B).

Expanded and/or recessed keyboards are examples of direct selection aids which can provide a child with an independent means of writing (Figure 3C) and portable direct selection aids have been developed to provide children with pointing ability (even children with very limited pointing skills) with a portable independent means of communication (Figure 3D).

C. REVIEW OF EXISTING COMMUNICATION AIDS*

SCANNING AIDS

The scanning type of communication aid is currently the most common form of communication aid. Basically, these aids consist of an indicator which scans sequentially through a display of pictures, symbols, or letters until signalled by the user. The scanning aid then displays or prints the character, resets the indicator, and starts scanning again until the next character is selected, and so on. The major advantages of an aid in this category are:

1) it is a simple aid and, thus, has good reliability
2) it requires very little effort to operate
3) it can be used by anyone no matter how severe his physical disability or how little control he may have over his movements as long as there is some movement that can serve as a recognizable signal.

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*This descriptive survey does not include all of the aids in each of these categories. These aids are presented to provide a representative profile of the different types of aids which are currently available or under development. A more comprehensive listing and description of these aids and other aids may be found in an Illustrated Digest of Non-Vocal Communication and Writing Aids for Severely Physically Handicapped Individuals (Available Summer 1977), (See Appendix A).

The major disadvantage of these techniques is their slower speed. The child must wait while the indicator stops at many unwanted letters before the indicator reaches the desired character. The rate of scanning must stay relatively slow because the indicator must rest on each selection long enough for the child to select it without error.

Many different variations of this technique have been developed. The simplest form is a disc with a rotating arrow. The Rotocom developed by the Trace Center (Madison, Wisconsin); the Rotating Pointer of the Ontario Crippled Children's Centre (Toronto, Ontario); and the Communicator distributed by Adaptive Therapeutics (Madison, Connecticut) are a few of the many examples of scanning aids which utilize a rotating arrow.

A device that scans by illuminating the letters was developed by Centre Industries (New South Wales, Australia). The aid controls a typewriter, providing printed copy. A two-speed linear scanning aid is available from PMV (Stockholm, Sweden) which controls standard IBM typewriters.

Several groups have developed aids which utilize the row-column scanning pattern. With these aids, a larger number of selections can be presented without requiring great amounts of time to select them. The increased efficiency, however, requires that two signals be given for each letter selected. The MC-2 Matrix Communicator developed by DUFCO (Cambria, California) uses this technique and provides a simple illuminated display which can be used with pictures, symbols, or letters. The Tufts Interactive Communicator (TIC) developed at Tufts University (Boston, Mass.), also uses the row-column scanning technique and has a Burroughs display and a strip printer as two of its output forms. The Linguaduc Scanner produced by Carba (Switzerland) uses one or two switches to control a Facit printer. POSM Research Projects (Aylesbury, Bucks., England) produces the POSSUM device which uses a typewriter as its output form, as does the Zambette Electronics, Ltd. (Essex, England) System 8 Unit. The POSSUM typewriter features a simple sip-puff switch and chin switch, while the System 8 unit features a "magic" capacitance switch and projection system for displaying typewriter output on the wall or ceiling. The Comhandi produced by Physico-Medical Systems (Montreal) controls teletype as its output form. The Cybernetics Research Institute (Washington, D.C.) has a scanning communication aid called the Whispertype which controls a typewriter and can be used with a variety of input sensors.

The Alphabet Message Scanner developed by Prentke-Romich (Shreve, Ohio), is an example of a row-columm scanning device which can be used either as a simple aid or to control a typewriter to function as an independent aid. A completely portable scanning aid has been developed by Vendacom (Brooklyn, New York). Called the Porta Printer, this aid is built into an attache case and weighs just seventeen pounds. It uses a miniature strip printer as its output and can control two electrical outlets for the convenience of the user. The Strip Printer, a similar portable scanning aid, is marketed by Prentke-Romich (Shreve, Ohio).

Another scanning approach which can provide greater communication speeds is the directed scanning technique. The 100-100 MK-II display developed by the Ontario Crippled Children's Centre (Toronto, Ontario) is one example of such an aid.

A recent technique which has been developed to accelerate the scanning process is the "anticipatory" or "computer-aided" scanning technique. This technique was first introduced by the New England Biomedical Engineering Center at Tufts University (Boston, Massachusetts) and is now being incorporated into the newest version of Tufts Interactive Communicator (TIC). A computer-assisted (anticipatory) scanning system has also been implemented at the Northwestern University Rehabilitation Engineering Center (Chicago, Illinois) using a PDP minicomputer.

In summary, the scanning approach is a particularly powerful approach because it can be used with almost any individual no matter how severe his physical handicap. This is possible because these techniques can be controlled by any one of a number of input sensors or switches. These include breath switches, knee switches, impact switches, pull switches, proximity switches, whistle switches, and brain wave sensors, to name just a few. Thus, at least one switch could be found which could be operated by a given individual. The major setback of the scanning approach, again, is its limited speed.

ENCODING AIDS

Because speed is so important when communicating (especially when spelling is required), several research groups have developed aids which use encoding techniques instead of scanning techniques. The increased efficiency of signalling provided by the encoding approach increases the speed of communication. Here again, however, the increased speed requires a greater degree of control from the operator. More complex motions and more responses per letter are required. In addition, the encoding scheme must be learned before the aid can be used. The greater the number of switches used in an encoding scheme, the simpler the code will be. However, an increased number of switches requires greater dexterity on the part of the operator. Thus, a compromise between the two factors--simplicity of code and number of switches--must be worked out. Different research groups have chosen different balances between the two factors in the design of their aids. The specific needs of the individual determine which of the aids is best suited for him.

Centre Industries (Australia) chose a simple set of movements (two levels and a pause), as in Morse Code, to operate their C.O.S. unit which, in turn, controls a typewriter. Medical (South Burlington, Vermont) also has a Morse Code communication aid, called the MC-6400 which uses a television monitor as its output form. POSSUM Controls (Aylesbury, Bucks., England) uses a three-level code in one of their POSSUM units (sips, pauses, and puffs) which also controls a typewriter. The aid developed by Hengrove Ltd. (Berkshire, England) uses a four-level code (two degrees of sip and two of puff) which requires finer breath control but is faster. With the Electroid, one, two, four, or eight switches can be used to control a typewriter (Bucks., England). The Cybernetic Research Institute (Washington, D.C.) uses a still larger number of switches on their CYBERTYPE device. The CYBERTYPE uses an encoding scheme which utilizes fourteen switches arranged in two banks of seven. One switch in each bank must be selected to print a character. The aid may also be used with only seven keys by depressing two keys in succession.

The basic advantage that encoding devices have over scanning devices is greater speed, a very important factor. The encoding aids do, however, require that the operator have considerably greater dexterity. They also require that the operator learn a code of some sort before operating the aid. Clinics that have used encoding aids, however, report that the codes are often more easily learned and retained by the children than had originally been anticipated.

DIRECT SELECTION AIDS

Communication aids in this category have the greatest number of switches, one for each symbol or character on the aid. To obtain a character, the user simply operates the switch corresponding to that letter and that letter only. One obvious advantage of this type of aid is that there is a one-to-one correspondence between the switches and the symbols, making instruction very simple and straightforward. The active selection of the exact letter also provides very good direct feedback to the user. These aids are particularly well-suited for use with young children. And direct selection systems tend to be more rapid than scanning systems since there is no waiting for scanning indicators to arrive at the proper letter. The speed of communication is limited only by the user's ability to activate one of the aid's switches. These aids, however, require greater dexterity on the part of the operator who must have fairly good control of the gross motor movements of at least one of his extremities.

Some of the aids in this category are designed for persons with no arm or hand control but with fairly good control of some other portion of their bodies. MEFA GmbH (Bonn, Germany) makes an expanded four-tier keyboard for operation with one's feet or foot. Reva-Aids (Copenhagen, Denmark) makes an expanded proximity keyboard for use with cerebral palsied children. This keyboard can be operated either by foot or by headsticks. IBM makes special hand rests and arm rests which allow some weak and spastic individuals to operate the standard IBM electric typewriters. When used with the correctable IBM Selectric typewriter, these adaptations can provide the handicapped individual with a correctable communication aid. Furthermore, a special "Orator" type ball* is available, providing large, highly visible characters for the vision-impaired.

Several special keyboards have also been developed by PMV (Stockholm, Sweden) to enable use of the typewriter by severely handicapped individuals. A typewriter which is controlled by a light-pen attached to the user's head has been developed by M. Soede and H.G. Stassen (Netherlands) and is called the LOT (Light Spot Operated Typewriter).

Other types of aids include several telecommunication aids for the deaf which can be modified for the moderately involved child; these include the MCM Communicator marketed by SICO (Oakland, California) and the TV Phone marketed by TV Phone (Silver Springs, Maryland). A hand-held communicator which can be worn on the wrist has been developed by Canon, Inc. (Japan) in cooperation with Dutch researchers. The aid, called the Canon Communicator, uses a strip printer as its output. A completely portable communication aid which is built into a special wheelchair lap-tray and has the ability to work with letters, words, or phrases has been developed by the Trace Center (UW-Madison, Wisconsin). This unit, called the Auto-Monitoring Communication Board (Autocom), has a special sensing system which allows use of the aid by children with only very minimal pointing skills.

D. SUMMARY OF PAST WORK

As can be seen from the review, a great deal of work has been done in the area of the development of communication aids. Much work has yet to be done, however, before the aids will begin to be able to meet the needs of the severely physically handicapped individual. Although much progress has been made, much more will be necessary before the aids begin to meet the needs and constraints described in the first section of this report. In addition, much more work is needed besides just the creation of new communication aids. Communication development programs and information on the appropriate application and adaptation of communication aids is critical to the successful application of them. In addition, much more information is needed about the language development processes of the children if we are to be able to intervene early with them and provide them with effective means of communication during their critical early developmental years. Our entire approach to designing communication aids will also have to alter significantly in order to develop aids which can be applied to the problem of developing communication in very young or in severely mentally retarded individuals.

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*THIS IS A SAMPLE OF THE ORATOR TYPE STYLE.

SECTION II

OVERVIEW OF GRANT ACTIVITIES

A. TRACE CENTER PROGRAMS DURING THE GRANT YEAR

This grant reported here was part of a larger coordinated research/development/dissemination program at the Trace Center. The overall program at the Center was aimed at providing a balanced approach to research and development of communication aids and techniques for non-vocal physically handicapped individuals. This balanced approach provided major components in each of the areas of research, development, evaluation, information dissemination and training. Because the field was in a formative stage at this time, particular emphasis was placed upon research and dissemination of information on existing communication aids and techniques; this included research efforts of groups both in the United States and abroad.

The overall program of the Trace Center was funded through three grants (OEG-0-74-3321 Division of Personnel Preparation BEH and Contract OEC-0714-9057 and Grant OEG-0-74-7461 of the Division of Innovation and Development BEH) and had the following six components:

1) A State-of-the-Art Study of Non-Vocal Communication Techniques and Aids

This project, carried out in conjunction with several educational/clinical centers in the United States and Canada, sought to:

a. locate and document all existing non-vocal communication aids or techniques

b. identify the communication interaction needs of non-vocal physically handicapped individuals

c. evaluate the ability of existing aids to meet the needs of NVSPH individuals

d. make recommendations for future research efforts

The major products of this program were:

A State-of-the-Art Paper on Non-Vocal Communication Techniques and Aids,

An Annotated Listing of Researchers Working on the Problem of the NVSPH Individual,

A Bibliography of Publications in this Area, and a Master Chart of Communication Aids Covering Seven Countries

2) A National Workshop Series on Non-Vocal Communication Techniques and Aids

A series of three-day workshops on developing communications in the NVSPH individual were conducted in Chicago, Boston and Los Angeles. In addition to the materials generated by the workshop, a book was prepared based upon the transcriptions and has been published by University Park Press, Baltimore, Maryland.

3) An Ongoing Dissemination and Referral Program at the Trace Center

This has been a continuing program which was set up to handle the volume of inquiries received by the Center on both the specific efforts of the Center and on the research being done by others in the field.

4) Continuation of the Evaluation of Advanced Communication Aids (Autocom) as an Aid to Education

This program constituted the second year of the evaluation of the Autocom concept and the first-year evaluation of the portable version of the Autocom.

5) The Development of New Communication Aids to Meet Previously Unmet Needs

Activities in this area dealt with the development of aids ranging from very simple aids for mentally retarded individuals to advanced aids for children needing independent and flexible means of communication.

6) Exploration of New Research Areas and New Technologies

Projects in this area were quite small and were concerned largely with defining the respective areas and determining whether further effort was appropriate at the present time. The principle projects

> in this area dealt with three areas: the development of a universal interface switch set, investigations of the potential for voice-output from communication aids, and a pilot study of language development processes in the non-vocal child.

The activities covered by the grant being reported here dealt largely with items 4, 5, and 6 of the overall center program.

B. OVERVIEW OF ACTIVITIES COVERED BY THIS GRANT (OEG-0-74-7461)

This grant was a component grant covering seven different activities ranging from larger efforts such as the development of a new level of communications aids and small exploratory/informative studies such as the switch set study and the voice synthesis paper. Generally the activities can be broken down into three general areas: development of new aids to meet unmet needs, exploration of techniques extending the capabilities of existing aids; and research into the impact of communication aids with non-vocal severely physically handicapped (NVSPH) children.

A listing of the projects covered by this grant is presented in Table 1. The Formative Evaluation Rotocom project was a short project aimed at refining the design of a simple low-cost scanning aid. Original plans called for a re-design of an aid called the Rotocom to ease construction and lower the cost. During implementation, however, field review and clinical input greatly modified this particular project calling for exploration of a different approach identified by the teachers/clinicians. Efforts were then redirected toward exploring this new technique and comparing the two approaches.

TEACHER ADAPTABLE AIDS

The second project listed in Table 1, the development of the Teacher/User Modifiable, Developmental Communication Aids, represents one of the

TABLE 1

CATEGORICAL LISTING OF PROJECTS COVERED IN THIS GRANT

(OEG-0-74-7461)

1) The Exploration and Development of Communication Aids to Meet Needs not Met by Existing Aids
    - Formative Evaluation/Design of a Low Cost Scanning Aid
    - Teacher/User Adaptable, Developmental Communication Aid Program (Universal Control Module Aids)
2) The Exploration and Documentation of Technology to Extend the Capabilities of Existing Communication Aids
    - Switch Set Studies
    - Voice Synthesis Paper
3) The Exploration of the Impact of Communication Aids on the Education and Language Development Processes of NVSPH Children
    - Continuation of Case Study Evaluation of Autocom
    - Comprehensive-Comparative Evaluation Program Part I - Preparation/Planning
    - Preliminary Language Study Probes

two major efforts of this grant. Previous communication aids were very rigid in terms of their modes of operation. This meant that very little modification of aids to meet the needs of specific individuals was possible (aside from the input interface). It also meant that aids could not be purchased which could be simple enough for young children and flexible enough to grow with the child as he developed. Since communication aids are currently very expensive, growing out of aids is a serious problem. To meet these and other needs, this second project area was undertaken. Basically, it consisted of two parts. The first was the development of a new approach to communication aid design -- the development of a flexible control system which could act as the core for a wide range of communication aids. The second part of this program was the development of two prototype communication aids using this same control system.

SWITCH SET STUDY

The switch set study was conducted as a part of the development of one of the aids mentioned above. The objective of this continuing program is to profile the different known interface switch approaches and to provide a reference for commercially available switches. This phase of the program was directed toward developing the profile and toward assembling the first version of the reference for commercially available switches.

VOICE SYNTHESIS PAPER

The rapid advances in voice synthesis in recent years, coupled with the potential as an output form for NVSPH children, have raised considerable interest among those working with these non-vocal individuals. The purpose of the paper prepared in conjunction with this project was to provide teachers and clinicians with a brief summary of the different types of synthesizers currently available and to introduce some of the problems and complexities involved in producing synthesized speech.

The case study evaluation program for the Autocom was a continuation of a tracking study begun under funding from the National Science Foundation (EC40316). The purpose of this project was to track the continuing use of the Autocom by eight NVSPH cerebral palsied individuals in order to obtain information on the development of communication and academic skills in children using the aids and to identify ways in which the design of aids could be improved to facilitate the same.

COMPREHENSIVE EVALUATION PREPARATION

Based upon the preliminary findings of the case study evaluation, a more comprehensive evaluation of communication aids as facilitators of the educational process was planned. This grant was to cover the planning, preparation and subject selection for that evaluation program. Two thirds of the way through this process, however, it was learned that funds would not be available to conduct the actual evaluation. Efforts were then turned toward phasing down this program and transforming as much of the preparatory work as possible into a form that could be used by other research groups. The results were an evaluation Sourcebook, a report on some modifications of standard test materials and a survey report on factors of an evaluation program.

INITIAL LANGUAGE DEVELOPMENT

The final area of exploration covered in this grant dealt with preliminary explorations of the expressive output fo three of the children who were using portable independent (with a printout) communications aids. The objective of this preliminary study was to begin to analyze language patterns in the children's expressive output and to explore methods for evaluating their expressive language.

C. PROJECT SUMMARIES

A brief summary of each of the project areas follows. Included is a description of the rationale, objectives and a discussion of the procedures and major results. Following the project summaries is a discussion relating the results of this grant to other developments in the field and to future efforts. For more specific information on the various projects, please consult the respective sections in Part III of this report or write to the authors for more comprehensive documentation.

PROJECT BRIEF

1. FORMATIVE EVALUATION/DESIGN OF A LOW-COST SCANNING AID
(Full report is located on page 103)

Introduction

Many NVSPH children can be provided with effective means to communicate through use of communication boards where they point to message elements to express their thoughts. Many of the more severely physically handicapped children, however, are not able to point at all. For these individuals, scanning techniques or aids are the simplest, most effective initial approach. Several different scanning aids had been developed but none were available which were low in cost or designed for use with very young or mentally retarded children (circa 1974). A simple low cost aid called the Rotocom was, therefore, developed at the Trace Center (Figure 4). This aid consisted of a rotating pointer which could be controlled by a severely handicapped child by utilizing any body motion which the child might have control of. This rotating pointer could then be used as the child's finger to point to pictures, symbols, words, letters, etc. both for diagnostic and communicative purposes (Figure 5). Under previous funding, a first prototype of the aid had been developed. Field reaction to this prototype was very positive and resulted in requests for the aid when completed.

Objective of this Project

The original objectives of this project were simply:

- to field review the aid to secure additional comment and suggestions prior to re-design

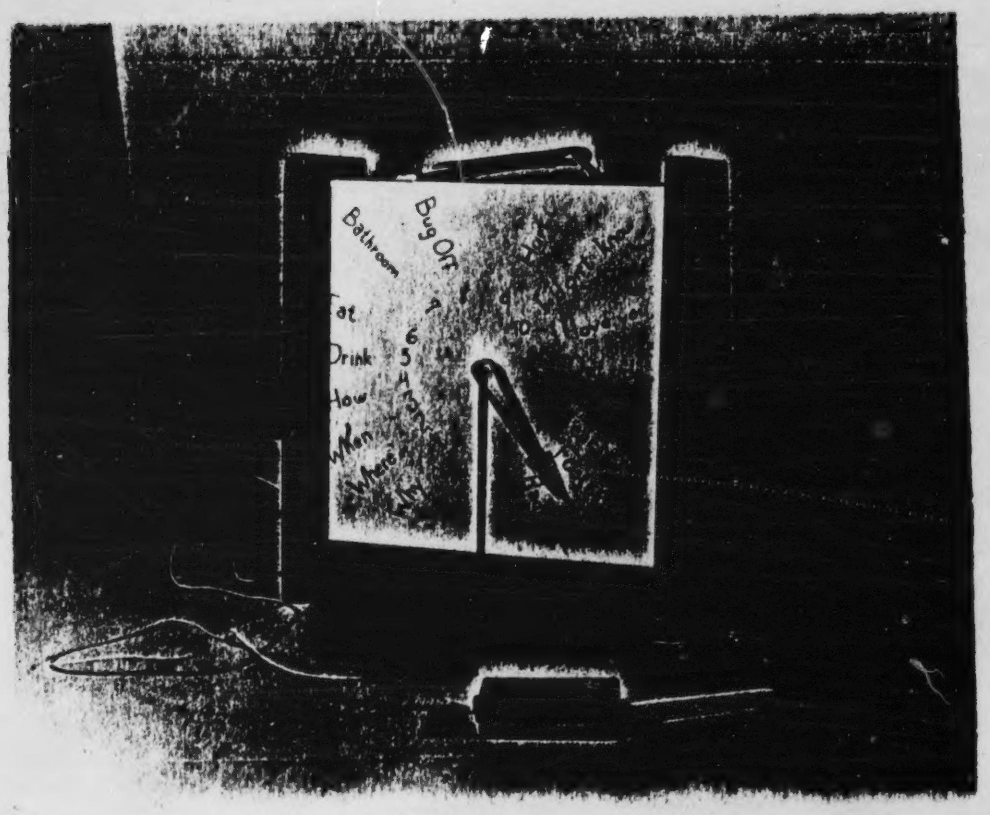

Bathroom
Bug Off
Eat
Drink
How
When
Where
7
6
5
4
3
9
10

FIGURE 4

Rotocom

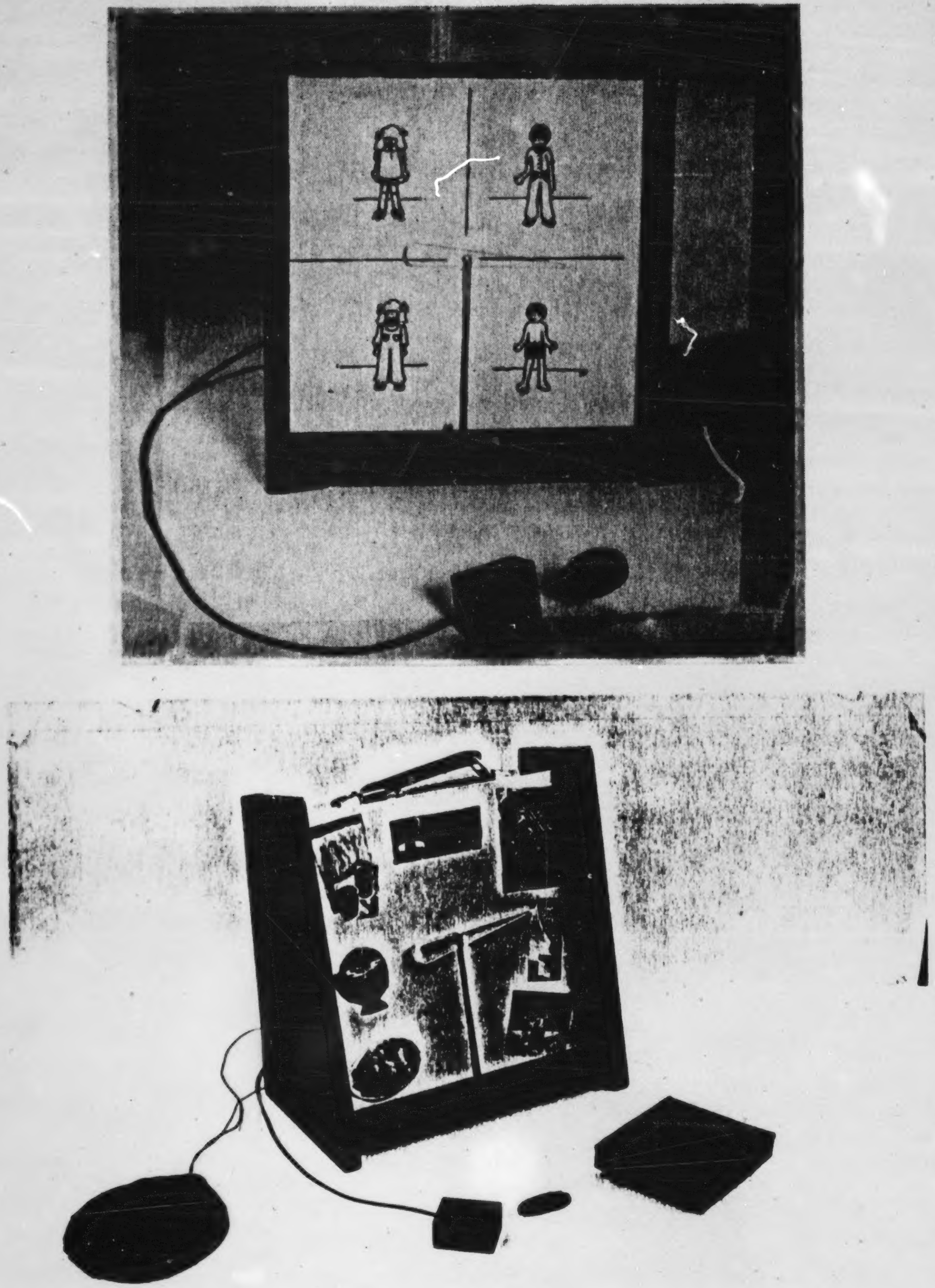


FIGURE 5

Rotating Pointer/Diagnostic & Communicative Purposes

- to re-design the aid so that it could be easily constructed at low cost

During the implementation of the project, however, a second approach for providing a very simple means of indication to young and mentally retarded children was presented by the teachers and clinicians working with the Rotocom. Some advantages were then pointed out for both the approach used in the Rotocom and for the second approach. About this time, Adaptive Therapeutics, Inc. came out with an aid called the Communicator which was very similar to the Rotocom. The combination of these two occurrences caused the research staff to reconsider its plan of action and a new plan was subsequently drawn up.

New Plan of Action and Objectives for the Simple Scanning Aids Project

Because of the new development, it was decided that the most appropriate way to proceed would be to temporarily hold on further development of the Rotocom and to direct whatever resources were available toward the definition of the alternate approach, and then to place the prototype along with a prototype of the Rotocom into comparative field evaluation situations. The relative advantages and disadvantages of the two approaches could then best be viewed in terms of convenience to the teacher, flexibility, and applicability to very young or mentally retarded children.

The specific objectives for the current grant then became:

1) to define the proposed alternate approach suggested by the field clinicians

2) to come up with a rough description of what the aid might look like and what its characteristics might be

3) to define what some of the advantages and disadvantages of each of the approaches might be

Actual design and field testing of the alternate approach would be done under separate funding from the Wisconsin Association for Retarded Children.

Implementation Notes

The alternative method suggested and subsequently explored involved indicating the message elements using lights rather than a moving arrow. Direct lighting of the element was felt to be much more direct than the concept of using a rotating pointer, especially for young or mentally retarded (MR) children.

Developing design recommendations for the alternate approach consisted of four major activities.

1) determining from teachers/clinicians the essential and desirable features of such an aid
2) determining the number of selections to be displayable on the aid
3) determining the optimum method for lighting the squares (corner light, backlighting, etc.)
4) determining the scanning pattern most suitable for young/MR children.

Table 2 lists the major considerations covered under each of the topics.

Test setups were constructed and teachers and clinicians were surveyed using the setups to secure information used in developing the design recommendations. For a more complete discussion of these parameters, see full report in Section III of this report.

Results and Use to be Made of Findings

The results of this project were two-fold. First, the generation of

TABLE 2

MAJOR CONSIDERATIONS IN DEVELOPING DESIGN RECOMMENDATIONS

Features/Capabilities of the Aid

- Essential Features
- Highly Desirable Features
- Other Desirable Features

Number of Selection Squares

- Minimum
- Maximum Without Causing Confusion
- Variable

Method for Indicating the Square

- Corner Lighting
- Edge Lighting
- Spot Backlighting
- Full Backlighting

Scanning Pattern

- Circular
- Left to Right
- Row-Column

the report delineating and discussing the parameters involved in the development of a simple aid for use with young or mentally retarded children. Secondly, the development of a set of design recommendations for the development of an aid based upon these studies.

The design recommendations are currently being implemented under funding from the Wisconsin Association for Retarded Children. Subsequent to the development and testing of this aid, a comparative evaluation of the rotating pointer aid (Rotocom) and the moving light aid can be conducted.

The results of these efforts along with the information gathered in this current study will be of use both to researchers in the development of new better aids, and to teachers/clinicians in evaluating or selecting aids for their children.

Results of this project will be available through ERIC, Accent on Information, Government Printing Office and the Trace Center Information/Resource Service.

2. DEVELOPMENT OF UNIVERSAL CONTROL MODULE BASED COMMUNICATION AIDS

(Full report is located on page 132)

Introduction

The last few years have seen a development of a whole new range of communication aids for severely physically handicapped children and adults. Portable aids, as well as aids which can print whole words, phrases and sentences are now becoming available to meet the needs of non-vocal severely physically handicapped individuals. These aids use a variety of different techniques, including scanning, encoding and direct selection,in order to meet the needs of individuals having different problems and abilities (Vanderheiden, Grilley 1976; Raitzer et. al., 1976; Luster, Vanderheiden, 1975). Although these aids represent significant advancements in the development of communciation aids, there are several areas where significant advances are still needed. A good example of these aids is the original Autocom developed at the University of Wisconsin-Madison. Although the aid did provide a portable means to communicate the ability to print out messages independently and the ability to be used with pre-spelling children, the aid was not correctable, was relatively inflexible, operated in only one mode (direct selection) and was limited in its adaptability to the varying of its input interface. In addition, the Autocom also suffered from the other common characteristics of communication aids of its class in that it was a low-volume and therefore, high-cost item and that it was maintainable only by its developer. Finally, the aid had only limited ability to function in a developmental manner (i.e., to start out very simple and to expand to meet the growing needs and skills of the child as he developed).

Because of the shortcomings such as these which were expressed by teachers/clinicians in the field, the Trace Center established a program to explore the development of a control module which could serve as the core for a whole range of very flexible/adaptable and compatible communication aids. Ideally, such an approach would allow teachers/clinicians some of the flexibility and adaptability inherent in the fundamental and simple aids but not previously available in independent aids, (Vanderheiden, Luster,1975. In addition, it could lead to aids which were lower in cost to develop, produce and maintain and which would all be able to use the same interchangeable accessories.

Objectives of this Project

The objectives of this project were to explore the Universal Control Module concept, and, if it proved feasible, to develop a prototype of such a module. It was hoped that a Universal Control Module (UCM) could be designed which would:

1) allow aids to be much simpler in operation in order to adapt to the individual needs of children
2) reduce the design time and cost for the development of new aids
3) allow for the development of a universal evaluation/training aid which could function in many or all of the different approaches
4) reduce the cost of independent aids while increasing their function

As the project progressed, however, the feasibility was established and a much broader role was seen as being possible for such a control module. The effort was, therefore, extended to try to develop a control module which:

1) would be able to serve as the control section for most any type of communciation aid, scanning, encoding, direct selection or combination

2) would be part of a universal control system which would comprise the bulk of the needed electronics for any given aid

3) would be very flexible and allow for maximum adaptability by the manufacturer, teacher/clinician and the user himself

4) would allow the design of "developmental" aids which could grow and expand function with an individual as he/she grew

5) would allow for easy access to and changing of a large vocabulary of words, phrases and sentences

6) would lower the cost of an aid below its cost if it were designed using discrete logic (by reducing number and complexity of sub-assemblies)

7) would lower costs of various aids using the system since it could be produced in larger quantities

8) would allow for lower maintenance cost and wider availability through self-diagnostic capabilities and common sub-assemblies and electronics across aids

9) would provide other researchers as well as research clinicians/teachers with a flexible core mechanism around which they could implement their new ideas and develop new types of aids for specific users without having to develop all the support materials, documentation and production/maintenance mechanisms (and thus lower the cost to develop new aids)

10) would allow for the use of a common set of accessories and materials across a wide range of fully compatible aids

As a separate project within this grant, it was also proposed to develop independent scanning and encoding aids with features similar to the Autocom. As the Universal Control Module progressed, however, it became evident that aids utilizing the UCM would be far superior to aids developed around the original Autocom electronics. The design of the scanning and encoding aids, therefore, was conducted as an extension of the UCM program. (Under separate funding, the Autocom itself has also subsequently been re-designed to use the UCM.)

Implementation Notes

As mentioned previously, exploration and development of the UCM concept proceeded faster than anticipated. As a result, a field testable prototype of the UCM was attained during the first year. In addition, prototypes of two communciation aids called the Versicom and the Autocom-E were developed using the UCM system. Actually, the word "aid" is a little misleading. The Versicom and the Autocom-E are actually package formats containing a UCM system plus a lightboard (Versicom) or a reed matrix board (Autocom-E), see Figure 6. Each of the package forms is capable of being programmed to operate in a great many different ways (Figure 7). As such, many completely different aids can be realized from just these two package formats.

The Versicom package is an outgrowth of the scanning aid development program and is capable of all the scanning techniques identified to date. It is also capable of operating in several encoding and direct selection modes.

The Autocom-E for encoding package is an outgrowth of the encoding aid development program proposed in the original grant. The Autocom-E is capable of operating in any of the encoding modes identified to date except those requiring lighted displays. (Those requiring lighted displays are better implemented on the Versicom.) The Autocom-E is also capable of being programmed to function as an improved Autocom.

Although the auto-monitoring technique or Autocom technique is the only

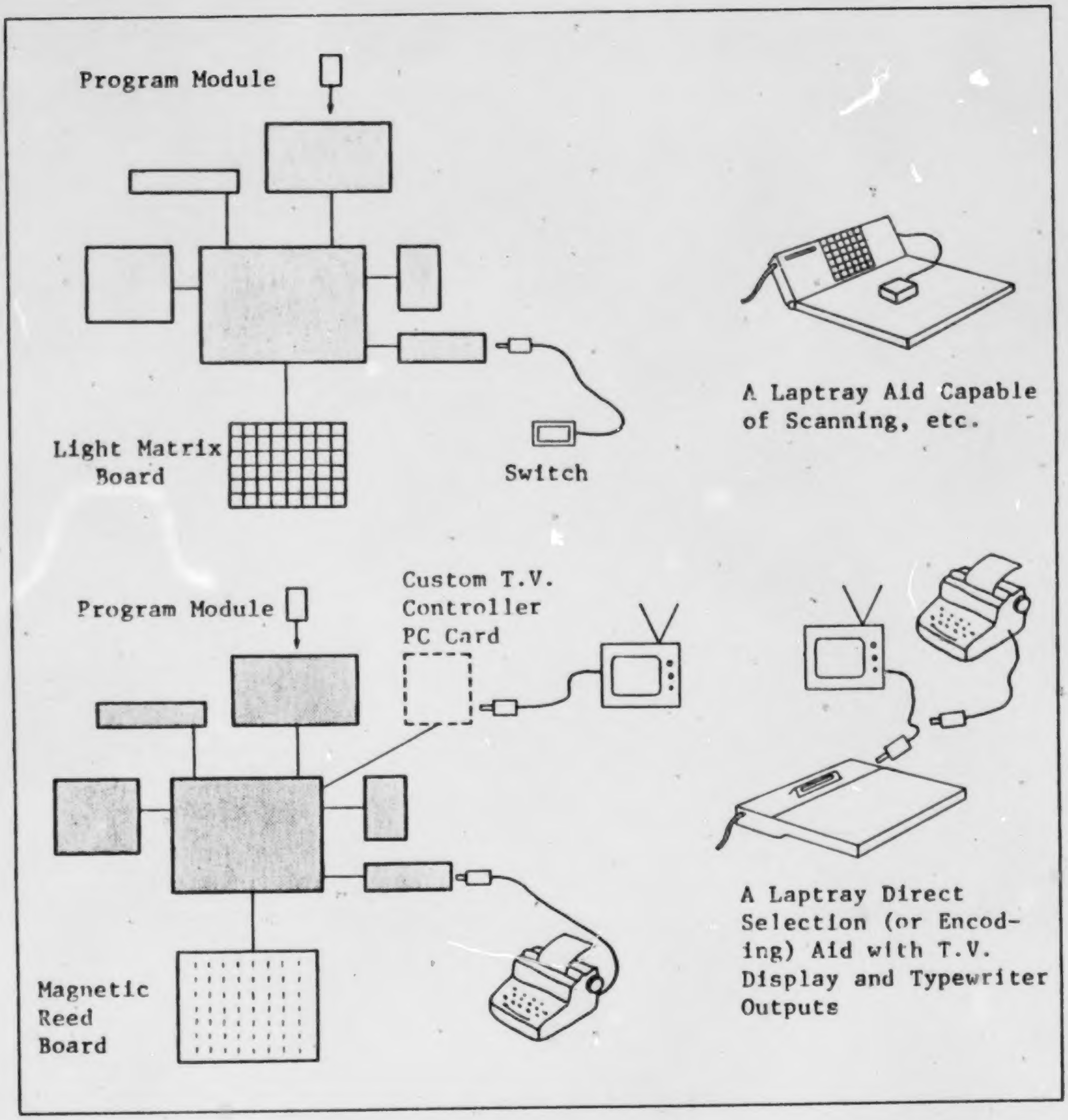

Program Module
Light Matrix Board
Switch
A Laptray Aid Capable of Scanning, etc.
Program Module
Custom T.V. Controller PC Card
Magnetic Reed Board
A Laptray Direct Selection (or Encoding) Aid with T.V. Display and Typewriter Outputs

FIGURE 6

Versicom & Autocom Package

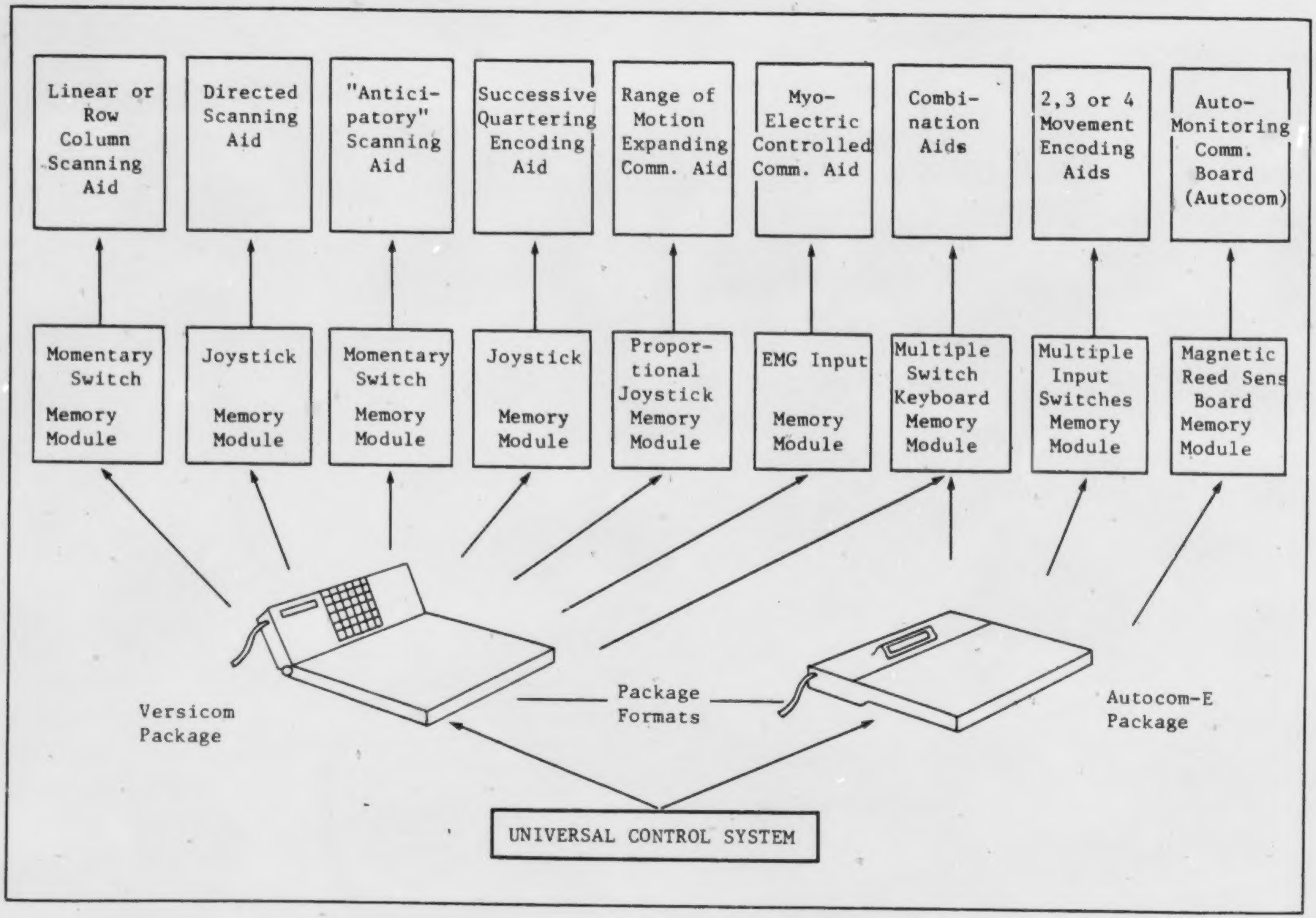

Linear or Row Column Scanning Aid
Directed Scanning Aid
"Anticipatory" Scanning Aid
Successive Quartering Encoding Aid
Range of Motion Expanding Comm. Aid
Myo-Electric Controlled Comm. Aid
Combination Aids
2,3 or 4 Movement Encoding Aids
Auto-Monitoring Comm. Board (Autocom)
Momentary Switch Memory Module
Joystick Memory Module
Momentary Switch Memory Module
Joystick Memory Module
Proportional Joystick Memory Module
EMG Input Memory Module
Multiple Switch Keyboard Memory Module
Multiple Input Switches Memory Module
Magnetic Reed Sens Board Memory Module
Versicom Package
Package Formats
Autocom-E Package
UNIVERSAL CONTROL SYSTEM

FIGURE 7

one of the modes of operation of the Autocom-E unit, the unit was named Autocom-E because it utilizes the same general packaging approach developed in the Autocom project and because of its ability to function as an Autocom as well as the many encoding modes of operation.

Results

At the end of the first year of this program, a full prototype of the UCM had been developed along with a full prototype of the Versicom and a bench prototype of the Encoding Aid. (The Autocom capability had not yet been developed.)

Summary of the UCM Prototype

The result of the universal control module (UCM) project was the development of a universal control system (Figure 8) which could function as the heart of a large number of different types of communication aids. The features and capabilities of these different aids would essentially all be identical with the only difference being their package and their input form (i.e., different scanning, encoding or direct selection input/control techniques). Some of the features of the universal control module developed, which would also be features of an aid incorporating the module, are:

1) Portability - The unit has its own self-contained rechargeable battery pack. The entire universal control module with the accessories shown in Figure 9 weighs approximately 3 pounds (batteries = + 3 more pounds) and would fit in a box approximately 5 x 15 x 50 cm., (2 x 6 x 20 in.)

2) Highly visible display - The characters on the LED display have an effective image height of .16 and with normal vision, can be read up to a distance of 3 meters (10 ft.). The character format is that of a standard 16 segment display (Figure 10), which unfortunately is not the most desirable format tor use with young children Part of the field test procedure will determine whether

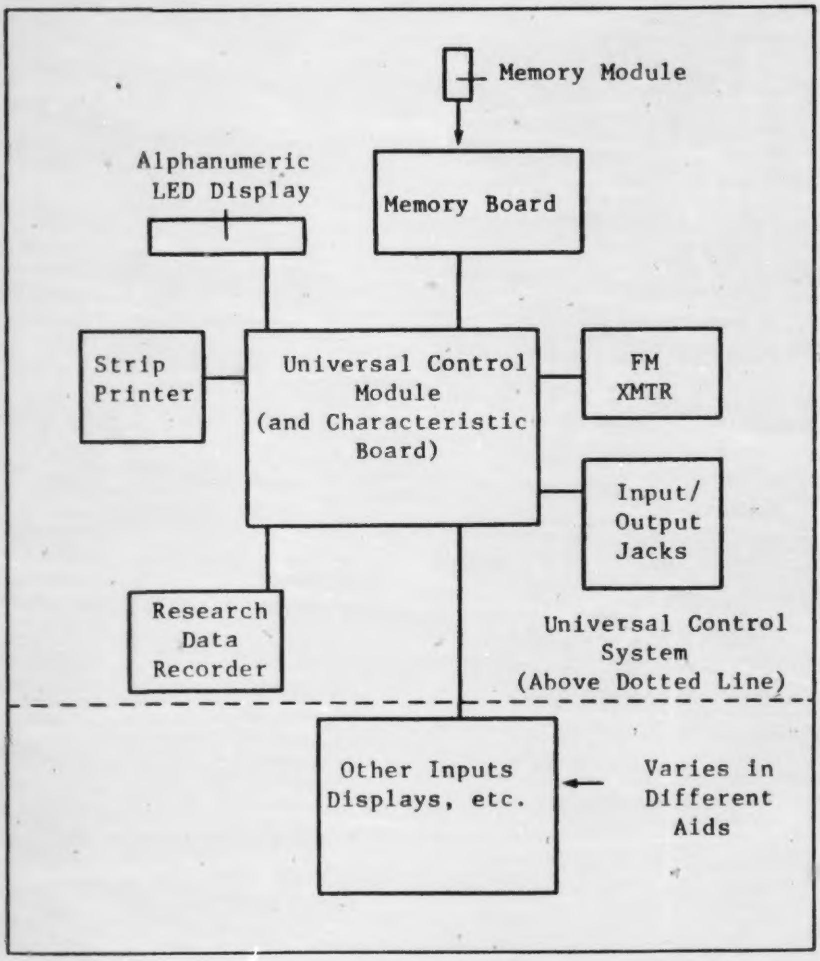

Memory Module
Alphanumeric LED Display
Memory Board
Strip Printer
Universal Control Module (and Characteristic Board)
FM XMTR
Input/ Output Jacks
Research Data Recorder
Universal Control System (Above Dotted Line)
Other Inputs Displays, etc.
Varies in Different Aids

FIGURE 8

UNIVERSAL CONTROL SYSTEM

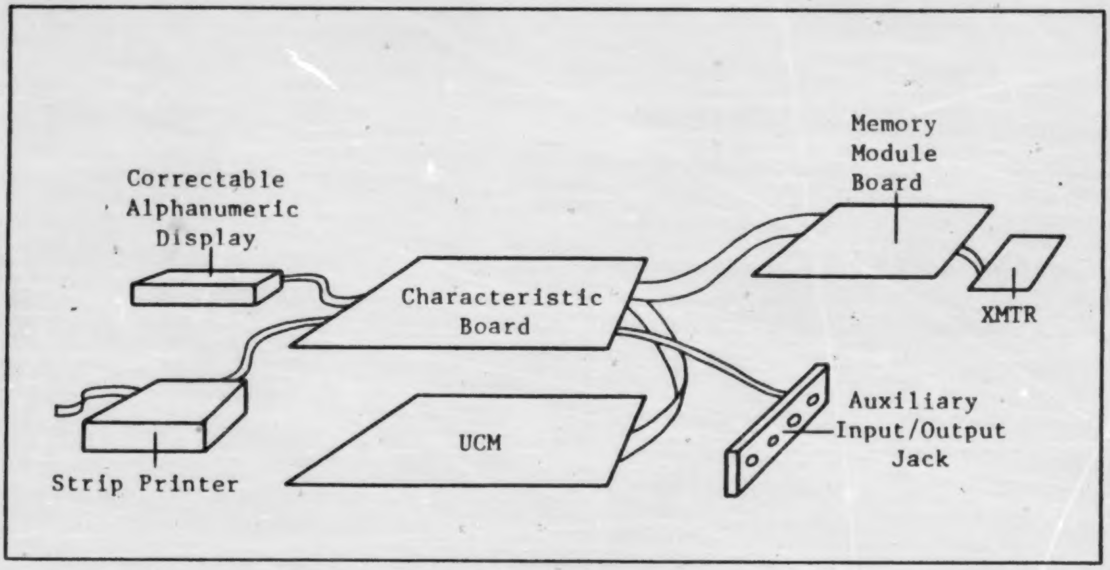
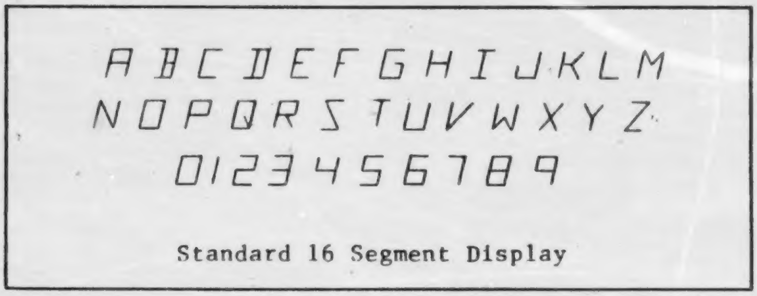

Correctable
Alphanumeric
Display
Memory
Module
Board
Characteristic
Board
XMTR
Auxiliary
Input/Output
Jack
UCM
Strip Printer

FIGURE 9

UCM WITH ACCESSORIES


A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
0 1 2 3 4 5 6 7 8 9
Standard 16 Segment Display

FIGURF 10

or not this irregular letter format is a problem for very young children. (Other displays could be substituted as they become available.)

3) Correctable display with printed copy - Because of special programming, the LED display, which does not normally allow for correction, is able to do both back space and backword functions to enable the individual to correct any errors in spelling or sentence construction as he sees them displayed. As the letters are printed on the display, they move from the right to the left. As they run off the left end, they are printed out on the strip printer so that even very long messages can be constructed and preserved using the strip printer without losing the ability to make corrections. In an alternate mode of operation, the letters are entered from left to right in a typewriter fashion and only shift when the display is full. By printing out the display each time it gets full, the shifting mode can be completely avoided if this poses a problem for some children.

4) The ability to print out words, phrases or sentences - In addition to printing out single letters, the universal control module has the ability to print out entire words, phrases or sentences with a single signal from the handicapped user. Commonly used words, phrases and sentences can, therefore, be programmed into the unit to provide more rapid and timely communication for the handicapped individual. This feature can also be used to store and output a series of commands to the aid or to other devices. The universal control module has the ability to hold up to approximately 2,000 words.

5) The ability to be used with pre-reading and pre-spelling children - Because of the ability to print out words and phrases, etc., the aid can be used with pre-spelling children having a sight word vocabulary. By using pictures or symbols in conjunction with the word on the child's display, the non-reading child would also be able to construct messages which could be subsequently read back to the child providing him with oral feedback as well as a motivating mechanism for providing associations between the picture and the corresponding word(s). Connected to a voice synthesizer such as the Votrax, the aid could both say and spell out the words on a display as the child pointed to the word/picture/symbol.

6) Versatility needed to adapt the aid to the specific needs of the child - The universal control module itself is capable of operation in almost any type of scanning, encoding or direct selection mode. Aids which incorporate module would be extemely flexible due to the program-ability of the module and would allow for extensive modification of

the particular operational mode chosen even after the aid is placed in the field.

7) Ability to function as a Developmental Aid - Because the aid can be easily modified even after placement, the aid can be made to develop slowly with the child. The aid can be easily programmed to operate very simply when placed with a young child. Then as the child develops, the aid can be modified by the parent or teacher by simply changing the plug-in modules to meet the advancing communication and control needs of the child as he grows and to take advantage of developing physical and conceptual abilities in the child.

8) Ability to have the child himself change words/phrases in the word-master - Up to approximately 80 words can be added or changed from day to day by the handicapped user (or teacher) to meet the changing communication needs of the handicapped individual. Frequently used words, seasonal greetings, favorite quips, emotional expressions and prepared remarks are some uses for this feature. It can also be used to easily alter his permanent word store and to store series of commands for the aid or for control of devices in his environment or employment situation.

9) The ability to easily interface with a wide range of accessories - Since the output of the aids are under software control, any length serial output string using any code can be programmed. Some examples would be 8 bit ASCII, used by most computers, 5 bit Baudot used by the deaf teletypers, 9 bit EBSIDIC used by IBM, and special code such as the 6 + 2 bit code used by VOTRAX.

10) The ability to be programmed by researchers and applications engineers to incorporate their own special features/capabilities - The COSMAC is a very easy microprocessor to learn and use. Because of the design of the UCM software, programs could be written by other researchers to expand the function of the aids or to develop new aids using the UCM system.

11) Ability for limited self-diagnostics and ease of maintenance - Special diagnostic programs can be prepared to help the technician in locating problems in the aid. Because it is a static processor, the aid can be stepped through its programs further simplifying maintenance. Since a large number of different types of aids could all use the same basic system, populations of users could be denser allowing for the setup of local or regional maintenance centers.

12) Ability to provide special functions for education, recreation, independent living creativity and employment - Special functions

such as calculators, sequence programmers, games, and device control could be easily added to the aid by simply plugging in special program modules. A special accessory could also be developed which would allow handicapped individuals to write their own programs for their aids.

13) A lower cost than comparable non-microprocessor based aids - the cost of the aid would be less than a non-flexible aid having only the capabilities numbered 1, 2 and 4. Aids which have only a single mode of operation and spelling only (no significant word output) could, however, be more inexpensively designed with a micro-controller or discreet logic and would not benefit from the UCM approach.

Summary of the Versicom Development

The Versicom was designed to provide a package form for implementating lighted selection display based techniques. The Versicom consists basically of a UCM system and a 64 square lighted selection display housed in a laptray compatible case (Figure 11). In developing the display for the Versicom, many different display illumination approaches were explored and field tested with teachers/clinicians for use in the selection display. Included were corner lighting, edge lighting, spot back lighting, and full back lighting techniques. Since full back lighting was much more highly preferred by teachers/clinicians than the other forms it was adopted in the design. Similar field review was also used to determine the package format for the Versicom.

Only a single scanning mode of operation was developed for the Versicom during the first year. The unit was, however, designed so that it could be programmed for most any scanning technique, including row-column, group-item, directed, incremental, and "anticipatory" scanning. In addition, the Versicom could be programmed to operate with or without its display to operate in a number of encoding modes including Morse, 2 to 10

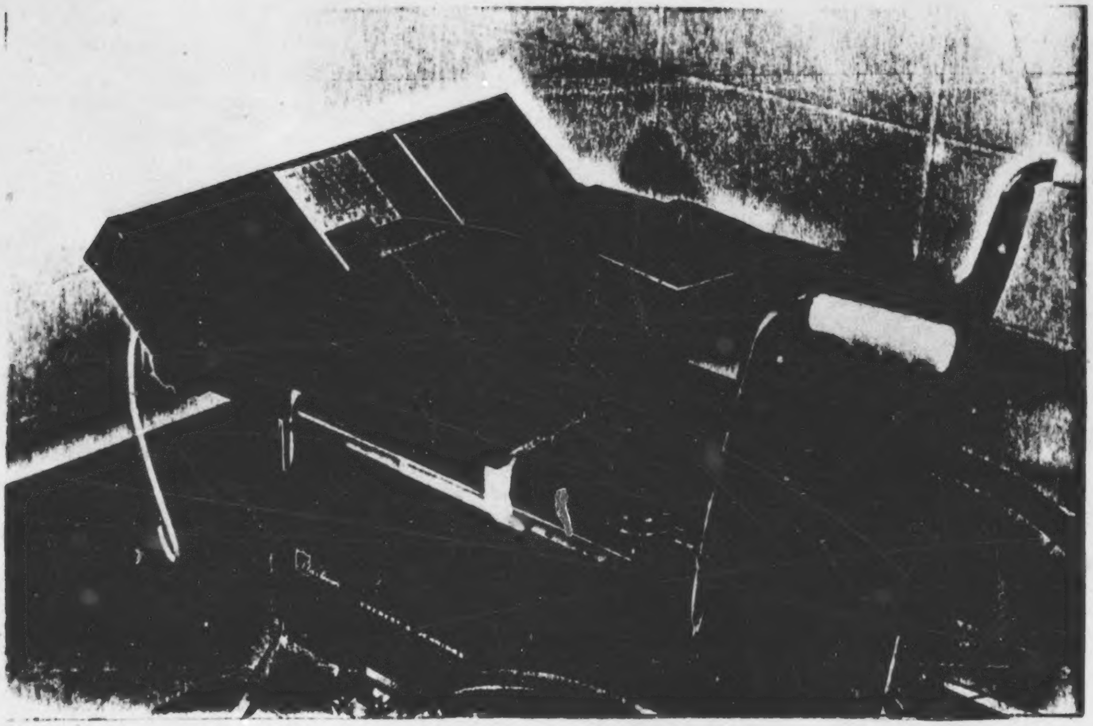


FIGURE 11

VERSICOM

switch multiple movement encoding, successive quartering, and 2 or 4 level sip and puff.

Summary of Encoding Aid

The Encoding Aid development was carried on as an integral part of the Versicom program since many of the same techniques (the non-display based techniques) could be implemented with either aid. The goal in designing the encoding aid was to provide a convenient format for non-display based aids. The potential for combining encoding techniques with features of the Autocom was also explored. As a result, a package format similar to but easier to construct than the original Autocom was decided upon. The Encoding Aids package development did not progress as rapidly as the Versicom and the Encoding Aid was still in an unprogrammed bench prototype form (essentially a UCM system with input switch) at the end of this first phase of the program. When completed, the aid will be able to operate in most any non-display based encoding or direct selection techniques using any number of external input switches from 1 to 12 or internal switches from 1 - 128.

Continuing Efforts

The UCM aids program is continuing under funding from several sources. The continued development and field testing of the Versicom and the encoding portions of the Autocom-E are supported under Grant #G007601628 from the Bureau for the Education of the Handicapped (OE). The development of the Autocom capability for the Autocom-E is being carried out in conjunction with an Aids Availability Program at the University of Wisconsin. Through this program, 40 UCM based aids will be constructed on a cost basis for individuals and centers across the U.S. and Canada as part of an open evaluation program in early 1977.

Cooperative programs have also been set up with the Trace Center by other research groups. The Blissymbolics Communication Foundation and the National Research Council of Canada are having a portable Bliss Symbol Printing communication aid developed using the UCM to assemble and "draw" the symbols on 2 1/4 in. wide tape (Figure 12). The Artificial Language Laboratory at Michigan State has also established a cooperative program to explore the use of voice synthesis as an output form for portable independent communication aids. The Swedish Institute for the Handicapped (Handikappinstitutet) and the Royal Institute of Technology (Sweden) have also initiated discussion regarding cooperative research/development programs around the UCM aids.

Continuing efforts in this program area will be centered around identifying and further reducing major cost components of the system, increasing its flexibility and ability to meet the needs defined by teachers, clinicians and other researchers and increasing the aid's abilities to be developmental and grow with a child. It is hoped that by August 1977 the hardware designs of the UCM system can be frozen such that future developments/improvements can all be implemented in software. This will help ensure the same flexibility, maintainability and compatibility for all aids using the system and facilitate its use and further development of other groups.

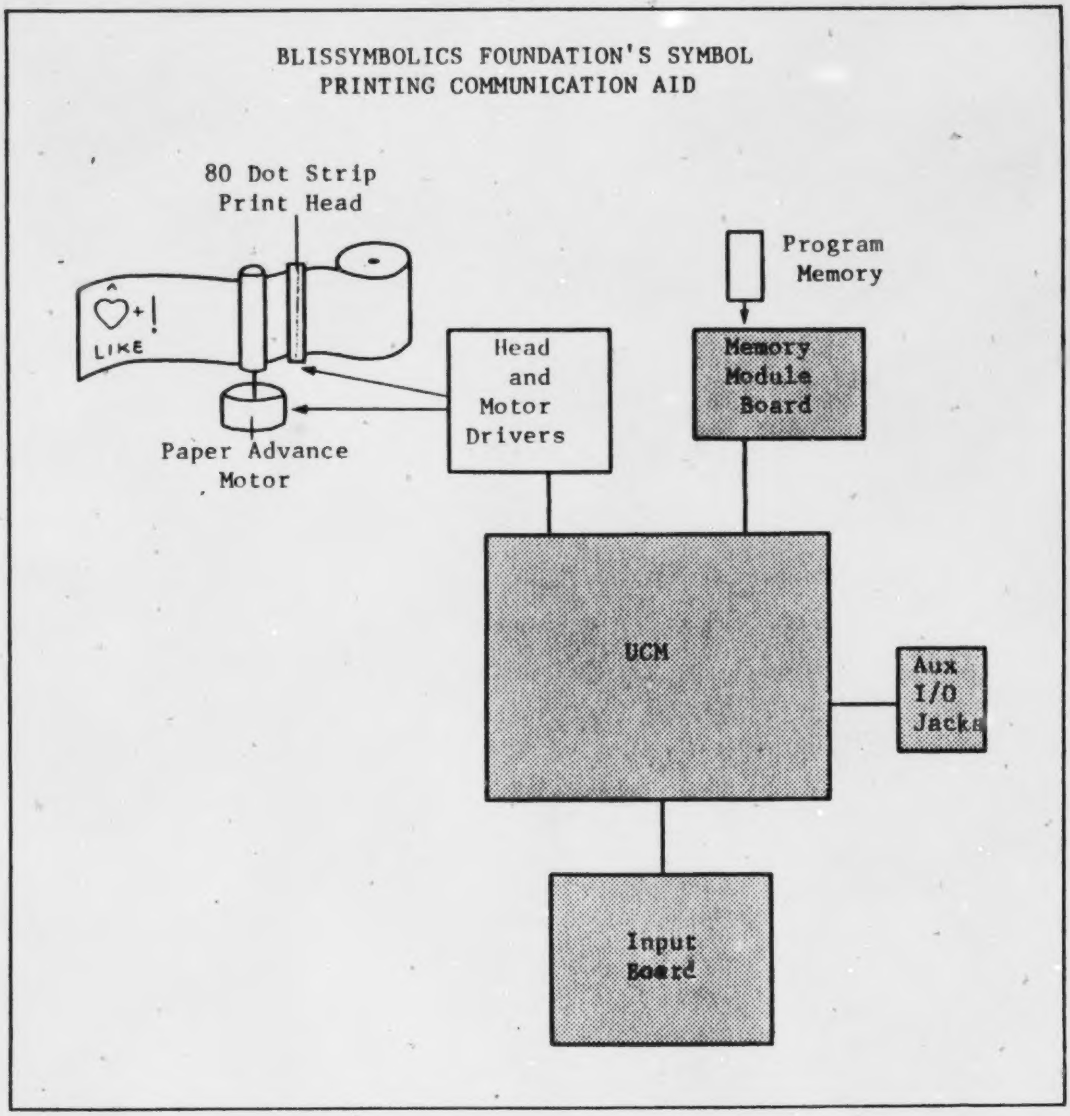

BLISSYMBOLICS FOUNDATION'S SYMBOL
PRINTING COMMUNICATION AID
80 Dot Strip
Print Head
LIKE
Program
Memory
Head
and
Motor
Drivers
Memory
Module
Board
Paper Advance
Motor
UCM
Aux
I/O
Jacks
Input
Board

Figure 12. Use of the UCM System to Create New Aids to Meet Other Needs

PROJECT BRIEF

3. SWITCH SET STUDIES
(Full report is located on page 167)

Introduction

Most communication aids require an input interface or switch of some type. Moreover, effectiveness of an aid with a particular individual and the speed and ease with which an individual can control an aid are both directly related to the appropriateness of the input switch or approach to the particular disability and abilities of the handicapped individual. For these reasons, it is very important that the individual trying to fit a handicapped individual with an aid be aware of the different types of switches that have been developed in order to be able to select the most appropriate approach or switch for the handicapped individual.

Many different types of switches have been developed or experimented with to date. Some are similar in appearance but operate on totally different principles. Others take different forms but operate on the same principle. It is, therefore, often difficult to compare the switches to each other or to determine the relative advantages of the switches with different types of individuals. The long range goal of this program area is: a) to provide summary information on the different approaches which have been explored and the different switches available and b) to provide application information on the use and applicability of the different approaches with different handicapping conditions. The efforts covered by this grant fall into objective a.

Objectives

The specific objectives of this phase of the program (the work covered under Grant OEG-0-74-7461) were:

1) to locate and identify the different types of switches which can be used as interfaces between severely handicapped individuals and special communication or control aids

2) to provide a preliminary profile of these different types of switches in a format which would make this information useful to teachers, parents and researchers

3) to begin a listing of commercially available switches along with profile information on them

Implementation Notes

The information contained in the report is the result of extensive literature searches and was conducted in conjunction with the research on independent communication aids and through direct consultation with other researchers in the field.

Results and Use to be Made of Findings

The primary results of this program are:

- the profiling of currently known techniques or approaches for providing an interface for severely physically handicapped individuals

- the initial compilation of commercially available interfaces

- the generation of a report documenting the above

The profiling of the currently available switches will be useful from two perspectives. First, it provides clinicians, teachers and rehabilitation engineers with a source of ideas to stimulate their thinking in solving the problems of specific individuals. Secondly, it provides a first version of a common terminology which can facilitate intercommunication and development in this very important area.

The listing of the commercially available switches is very preliminary and rapidly outdated. Updates on this aspect of the program, however, will be continual. A large problem in this area at the present time is that most switches that have been developed are available only with particular aids and not independently. These switches are not listed as commercially available (as switches), but are covered within the profile of interface approaches. Hopefully, over time, the availability of switches will become separated from that of individual aids, thus greatly increasing the applicability of all aids.

The Switch Set Report itself is divided into two sections: 1) the input switch profile and 2) commercial switches currently available.

The set of switches on which the profile is based includes: 1) commercially available switches that are available separately, 2) commercial switches that are available only as part of an aid or system 3) switches that were developed customly for individuals and 4) switches that are still experimental. Table 2 in the report provides a listing of the switch types profiled in Part One of the report. Included with each entry is brief summary information on switch activation procedure(s) or user movements required. Illustrations are used when appropriate but are avoided to prevent narrowing of a particular category because of physical configuration.

Part Two of the report provides summary information on commercially available switches identified to date. Included with each entry are the name of the switch, its manufacturer, descripton, activation pressure, special features, price, and delivery time. For the purpose of this report, a stated price and delivery time are necessary for a switch to be considered commercially available.

Overall, the report provides a preliminary reference and resource listing on input interface switches for communication and control aids. It also provides an organized framework for cataloging and describing the various types of switches. Its use to the teacher and clinician in the classroom or clinic, however, is still limited. Only a small portion of the different approaches are represented with commercially available is switches in the switch chart. Even more important, though, is the need for good practical application information on the different approaches or switches describing their advantages, disadvantages and applicability with different types of individuals and different environments. Most of the teachers/clinicians who will be working with these individuals will not have the time or resources to obtain or explore the many different types of switches available. Simple, practical, comparative information on the different approaches is, therefore, needed for the teacher/clinician. The development of a kit containing switches representing the major types or approaches should also be explored. If a practical switch profile kit can be developed, it could be made available on a loan basis to teachers/clinicians working with a handicapped individual thus allowing direct exploration of the handicapped individual's abilities.

PROJECT BRIEF

4. VOICE SYNTHESIZER
(Full report is located on page 191)

Introduction

Employment of a voice synthesizer with a communication aid for the non-vocal severely handicapped individual presents us with both an array of advantages and disadvantages. These advantages/disadvantages are directly related to: 1) the current limitations of voice output mechanisms and 2) practical applications (potentials and constraints) of a synthesized voice to facilitate a communication's aid.

There are four major types of voice synthesis: 1) recorded voice, 2) digitized voice, 3) continuously controlled voice synthesis and 4) phoneme voice synthesis. These types group according to how the voice is produced. Recorded and digitized voice are stored speech techniques (i.e., the human voice is stored on a tape or is converted to digital numbers and stored electronically). The second technique for producing automated speech is synthesized speech (i.e., speech which is produced [rather than recorded and played back] by a machine). Continuously controlled voice synthesis and phoneme voice synthesis employ this technique.

Convinced that a feasibility study to determine potentials as they apply to a communication aid with a vocal output was appropriate and necessary, and that such a study would provide valuable information for clinicians, teachers, and others in the field of communication, we undertook to do the following:

Objectives

The objectives of this mini-project were:

1) to define some of the potentials and limitations on the use of voice synthesizers as output forms for communication aids

2) to secure clinical reactions to the use of voice synthesizers and to the voice quality of existing units

3) to explore the problem posed by the need to insert inflection in the synthesized speech

4) to produce an article which could be used by teachers/clinicians to acquaint them with the potentials and problems in using synthesized speech

Results and Use to be Made of Findings

The result of this mini-project is an article titled "Use of Voice Synthesizers with Communication Aids for Non-Vocal Severely Physically Handicapped Individuals - Problems and Potentials." (See Part III of this report.) This article can be broken down into three parts:

1) discussion of the various forms of automated speech

2) considerations in the application of voice synthesizers with communication aids

   - vocabulary
   - inflection
   - English to phonetic translations
   - phonetic production by non-vocal children
   - speech consideration
   - voice quality
   - voice synthesis vs. printed output

3) voice synthesizers and oral-speech development

The first portion is largely introductory and definitional. It describes the major types of automated speech and differentiates stored speech from speech synthesis. The second section forms the bulk of the article and describes various aspects of synthesized speech and its use as an output form to communciation aids. Included in this discussion are several comparisons with printed output currently being used with these communication aids. Of particular interest are the comparisons of complexity and speech which show the synthesis approach to be about equally as slow or slower. Also discussed are the problems of inflection and phonetic input. The results of an evaluation of speech quality and intelligibility which was conducted by teachers and speech clinicians have also been included.

The third section is a short discussion of the possible implications of the use of speech synthesis on the development of oral speech skills in the severely dysarthric individual. The article is currently being updated and submitted for publication.

5. CASE STUDY EVALUATION PROGRAM
(Full report is located on page 211)

Introduction

In order for teachers, clinicians, parents and others working with the NVSPH individual to be able to select and apply communication aids with their handicapped children, information is needed about the aids and their function and appropriateness for different children in different situations. In selecting aids for use in the educational environment, one needs to know about the capabilities of the aids in general, their advantages and disadvantages with different types of children, how they can be used to facilitate the education of NVSPH children, techniques and aids which are most useful in an educational setting, the shortcomings of aids in general and of particular aids, modifications that can be made in the classroom procedures or curriculum materials in order to facilitate use of the aids, and the value/benefit or cost/benefit ratio for purchasing an aid for a child. The only known systematic evaluation efforts to date have been those conducted by the Cybernetics Research Institute [Kafafian (1975)], the Crotched Mountain Foundation (1966), the Trace Center (1975) and the Tufts Biomedical Engineering Center (in progress) . Of these, only the latter two have directly addressed themselves to evaluating the effect of communication aids on the child's educational progress, language skill and self-concept, as well as evaluating the physical design and operational features of an aid. The Crotched Mountain Study was addressed to an evaluation of "the ability of cerebral palsied persons to manipulate and control a series of switches connected to various output devices," (1966). Success in the program was measured by the individual's ability to control one or more of a series of outputs through utilization of an appropriate switch. The Cybernetics Research Institute study included more observations of the use of communication aids for various classroom activities, but the major focus was upon the children's ability to use the aid. Specifically, the study was concerned with determining whether or not providing the children with a prosthetic aid allowed them to achieve "a usable and effective written communication capability," (Kafafian, 1973).

Neither of these studies directed major effort toward assessing the direct impact of a non-vocal communication aid on the language and academic skill acquisition rate of NVSPH children. This aspect has been most recently addressed by evaluations conducted by the Trace Center (1975) and the Biomedical Engineering Center - Tufts New England Medical Center (1975).

The Trace Center has been involved in the field testing of one of their aids, the Autocom, and the New England Biomedical Engineering Center is currently evaluating the Tufts Interactive Communication (TIC), a scanning aid.

The purpose of this evaluation project was to extend a pilot evaluation program on the Autocom which was begun under NSF funding (EC 40316) the previous year. Eight non-vocal severely physically handicapped children (cerebral palsied) ranging in age from 6 to 19 had been provided with communication aids. Five of the children were using stationary versions of the aid while three had been provided with a newly developed portable version. Some tracking of the children's educational programs had been conducted during the NSF developmental grant, but more longitudinal information was necessary in order to secure information needed to address the above mentioned questions.

Objectives of the Continued/Extended Evaluation Program Conducted Under this Grant

The overall objectives of the Continued Evaluation Program was to obtain additional information on the use of communication aids with school-aged children in order to: a) provide teachers, parents, etc. with information necessary to select and apply communication aids most effectively, and b) provide researchers and developers with information which could assist in the development of better aids to provide these children with means of communicating, interacting and securing an appropriate education.

The evaluation program consisted of five areas of study designed to:

1) obtain quantitative and qualitative information on changes in the rate of acquisition of math, language and spelling skills with the introduction of an independent communication aid
2) compare a portable word-letter printing version of an aid to a stationary letter only version of these same aids
3) study the effect of an independent aid on the children's adjustment in interaction at school and at home
4) examine and document the ways in which the aid was and was not able to be integrated into the existing curricula and classroom procedures
5) obtain information to assist in the design of better aids in the future

Implementation Notes

The data collection procedures utilized in the study were designed to obtain descriptive, investigative information relating to the interaction of each student with the communication aid, the use of the aid at home and at school, and the educational programs, curricular materials used with and/or implemented for the aid. Methods and procedures implemented included:

1) systematic teacher feedback system
including formal questionnaires, classroom activity forms, periodic tracking questionnaires, taped cassette feedback,

observational visits, and weekly phone calls

2) standardized achievement tests
test battery consisting of Peabody Picture Vocabulary Test, Raven Progressive Matrices Tests, Knox Cube Test, Columbian Mental Maturities Scale, Peabody Individual Achievement Test, and Boston Speech Sound Picture Test

3) parent contact and questionnaire
including questionnaires, home visits, correspondence and periodic phone calls

4) independent evaluation at Kennedy Memorial Hospital-Boston
one of the aids was placed at Kennedy Memorial Hospital and independently evaluated through the sensory aids evaluation and development center at MIT

At the same time that the Autocom evaluation program was being conducted, a comprehensive evaluation program was being designed and prepared to obtain quantitative data on the change in rate of acquisition of language and academic skill. The Autocom evaluation program reported here was also to be used to pilot test different techniques for obtaining quantitative information needed in the comprehensive evaluation. It was believed that enough quantitative information could be secured using these pilot measures to produce preliminary publications on the data. Collection of the quantitative data from children who were as diverse and severely handicapped as the children in this particular study, however, and who were located at such distances from the Trace Center (average distance was 110 miles) was more difficult than anticipated. As a result, the precise data needed to draw quantitative conclusions was not obtained. The problems encountered, however, were studied and documented and guidelines prepared for the conduction of future studies to avoid this problem. The remote field placements seriously affected only the quantitative information gathering and did not significantly hamper the efforts of the evaluation program to determine how and where the aids were or were not of benefit.

Results and Use to be Made of Findings

The results of the program are broken down into the five objective areas discussed earlier. The major results can be summarized as follows.

1) Effect on Acquisition of Math, Language and Spelling Skills

In this area, the information on educational facilitation by the aid was centered around four areas:

a) the amount of active participation on the part of the child

b) the amount and accuracy of assessment and program progress information obtainable by the teachers

c) the amount of one-to-one time needed to program for the child

d) the child's ability to interact and particpate in class group activities

Table 3 provides a summary of the information compiled regarding the educational facilitation through use of the independent communication aid in this study.

Active Participation

The principle aspects of the aid which contributed to this facilitation were the independent readouts and the visible correctable display. In facilitating interaction in the classroom and general educational environment, the portability and self-contained strip printer of the portable aids were cited. The major limitations posed by the aids centered around the lack of correctable printed copy which resulted in the teacher's having to copy work from the TV screen when it was completed. Also cited as being a major shortcoming was the lack of a visible correctable display to augment the strip printer on the portable aid.

TABLE 3

Summary of Information Regarding Education
Facilitation Through Use of Independent Communication Aids

Average Classroom Activities						Classroom Involving Use of the Autocom			
Hrs/Day 1:1 Inst.	Hrs/Day Group Inst.	Hrs/Day Phys. Ther.	Hrs/Day Other Actys.	Average Hrs/Day Use of Autocom	Total Hrs Spent in Academ. Inst.	% of In-Class Academ. Inst.	% of Class Disc.	% of Ind. Work	Situations Where Autocom was used Most
2 hrs.	2 hrs.	½ hr.	1½ hrs.	4½ hrs.	4 hrs.	80%	20%	100%	general communication, printed copy, art work, letter writing, math, playing chess
4 hrs.	2 hrs.	½ hr.	½ hr.	4 hrs.	6 hrs.	40%	20%	100%	general communication, letter writing, art work, computer programming, tests, creative writing, playing tic-tac-tow
4 hrs.	2 hrs.	½ hr.	1 hr.	4 hrs.	6 hrs.	80%	5%	80%	supplement other attempts at communicating (e.g., gestures), "hard copy" work, art work, letter writing
1 hr.	3 hrs.	½ hr.	1½ hrs.	3 hrs.	4 hrs.	60%	5%	70%	math, general communication, "hard copy" work
½ hr.	4 hrs.	1 hr.	1½ hrs.	2½ hrs.	4½ hrs.	30%	5%	70%	to supplement limited verbal communication all "hard copy" work, tests
½ hr.	3½ hrs.	½ hr.	1 hr.	2 hrs.	4 hrs.	70%	5%	80%	math, spelling and vocabulary development supplement other attempts at communication (e.g., gestures)

Facilitation of Assessment

One of the areas most commented on in relation to the evaluation was the increased ability of the teachers to accurately assess the capabilities of the children and to track the children's progress in their educational programs. Several aspects of the aids were reported to contribute to the increased ability to accurately assess the children's abilities and problems. First was the elimination of interpretation and inadvertent cuing on the part of the tester. Secondly, the children were able to work at their own pace without causing frustration or cumulative anxiousness on the part of the tester. Thirdly, and most importantly, the children were able to see and correct their own mistakes. This allowed the teachers to separate three types of errors that were identified in this evaluation program as being made by these children:

(1) physical error - due to activation of wrong key or square on aid

(2) production error - wrong word or tense produced, but child can recognize error when looking at word or sentence and correct it

(3) comprehension error - child makes an error which he does not recognize as such

The principle features of the aid that were identified with regard to facilitation of assessment were the independent output and a highly visible, correctable display.

Productive Time

The third area of benefit was increased productive time on the part of the children. The benefits were cited as being centered around the decreasing one-to-one interaction/instruction needed in the classroom and ability to find independent work and homework for the children. The major shortcoming cited here was the limited amount of information which could be held on the screen before it had to be copied off by a second person.

Interaction

Increased overall interaction was the fourth area described by the field centers. Although this was reported more from the users of the portable aids, it was also reported from some of the stationary aid users. Many of the lower language level children, however, were not sufficiently competent with the aid to use it for general interaction. These children relied more on other means of indication (gestures, etc.) for communication and used the aid primarily for academic activities.

Overall, the teachers reported that the aids' greatest effects on the student's skills/progress were providing the opportunity to complete tasks independently, the elimination of costly hours of one-to-one instruction, and the opportunity of students to see and correct their work.

2) Comparison of Stationary and Portable Aids

The major points of comparison discussed were: a) speed, b) use with pre-spelling children and c) increased interaction due to portability. Spoken word counts were conducted on the output of the children using the portable aids. Comparison of these word counts to the vocabulary contained in the wordmaster showed that approximately 40% of the words used were contained in the wordmaster. This results in a speed increase factor of slightly more than two times. The exact effect of the speed of communication, however, was found to vary widely and to be very dependent on the context of the situation and the context of the message. The importance of the speed was also found to vary from being very important in group discussions to moderately important in independent work situations.

The ability to study the aids used with pre-reading children was limited due to the fact that only three of the aids had the wordmaster feature and two of them had been placed with children who had good spelling skills. The third aid was used by an individual who although he was a poor speller, was constructing fairly complex sentences (see Table 4). Examination of the output of this child revealed that the presence of commonly used words in a pre-spelling fashion did assist him in constructing sentences which were interpretable by his teacher. Research is continuing in this area with aids which have more recently been placed with non-spelling and non-reading children.

The results showed that the children using the portable aids were able to use their aids for much more interactive communication than the children using the stationary version. Much of this, however, can be attributed to the language of the individuals, the family home style, the school set-up and the daily routine of the student. Because of the many factors affecting language interaction, no general conclusions were found through this program.

Overall, the evaluation program found that the extent of the benefits of a portable or word/phrasing printing aid were very dependent on the application of the aid.

3) Effect of Aids on Interaction and Adjustment

Although this is a very difficult area to assess in any definitive manner, earlier programs identified it as one of the areas of significant effect for aids of this type. It was, therefore, included as a component of this program to explore the reasons for the effect and to determine if there were ways to facilitate positive interaction benefits through better

TABLE 4

Samples of S_{CC} Output - With Teacher's Interpretation

Wordmaster words are underlined

Stimulus: "What did you do last night?"
I com and aet arie whoch NT.
Teacher: I come home and ate and watched TV.

Stimulus: "What did you do last night?
I eat stad and whot the flid of what qs.
Teacher: I ate steak and watched TV, "The Flight of the White Geese."

Stimulus: "What did you think of the new baby?"
Mr. Caswell is not look hem because eaey red.
Teacher: Mr. Caswell does not look like him because his eyes are red.

Stimulus: "How do you feel?"
I am hot and hot of head.
Teacher: He is saying he has a fever.

Stimulus: "Tell us about the weather."
It is suna and clod.
Teacher: It is sunny and cold.

Stimulus: "What do you think of Ford pardoning Nixon?"
Nixon is go nut.
Teacher: Nixon is going to go insane.

Stimulus: "How are you feeling today?"
I come home and eat whot TV bed 365 days nuts.
Teacher: I come home and eat and watch TV 365 days a year - nuts !!!

design of future aids.

Feedback from the evaluation program identified eight areas that were facilitated by the aids which resulted in positive changes in the children's interactions in relation to those in their environment (see Table 5).

Some of the effects dealt with the ability of the children to be able to accomplish something independently for the first time. This was seen as both highly motivational to the children and a mechanism whereby they could prove their capabilities by demonstrating them to their peers, friends and strangers. This latter capability proved to be very important for some of the children. A second area dealt with the ability for the children to express themselves emotionally and to dissent. Teachers and parents reported "deepening personality" in their children as their children began to freely express their feelings and opinions, wanted or otherwise. Teachers, parents as well as some of the handicapped individuals themselves reported a reduction in the burden on others and a resultant increase in their communication opportunities. The reduction in burden upon others also increased the individual's self-concept and facilitated the decrease in their concept of themselves as persons to sympathize. In several cases, increased communication ability and the ability to do academic work allowed the individuals to be placed in more advanced educational programs. In one case, a child was reported to have been partially mainstreamed with the help of a portable aid.

Overall, parents, teachers and clinicians all emphasized the role of the aids in the area of social/emotional developmental facilitation and encouraged any modification to the aid which would enhance these capabilities in the children. Increasing the speed of the children's communication

TABLE 5

Eight Areas Facilitated by the Aids Which Resulted in Changes in Children's Interactions and Relations to those in their Environments

- Ability to "do" independently
- Proof of capabilities, mental level to other
- Emotional expression
- Dissent
- Means to communicate - yielding greater interest in environment
- Reduction of burden to others
- Increased communication opportunity
- Ability to do certain things

facilitating the expression of emotional statements or comments were suggested as two means to do this.

4) Integration into Existing Curricula in Classroom Procedures

Information on the integration of the aids into educational procedures covered four basic areas:

a) utilization of the aids in the classroom
b) skills taught using the aids
c) compatibility with educational materials
d) compatibility with classroom set-ups and procedures

During the study, it was found that while in the classroom, the aids, particularly the stationary aids, were used more as academic/educational aids than as communication/interaction aids (see Table 6). As much as 80% (with average of 64%) of the children's work was done using the aids. Only two of the students were able to use the aids significantly (20%) during discussions and both had portable aids.

Specific skills taught through the use of the aids varied with each student. Subjects taught were primarily dependent on the skills acquired or the skills which the teachers assumed were acquired by the student prior to receiving the aid. Overall, the skills included arithmetic skills (from recognition of numbers to algebraic equations), sentence construction, spelling, acquisition of reading skills, vocabulary development, comprehension skills, computer programming and self-expression.

A major shortcoming in the aids was the inability to use pre-printed or pre-prepared worksheets. Some methods were developed to enable previously prepared materials to be used with the television output of the aid. However, some form of correctable printer was identified as being

Table 6
Description of Time Speng Using Autocom and Situations in Which it was Used for each Student

Subject	Amount of Time Used		Classwork Seatwork/Homework			Other Uses		Situations Where Not Used	Ability to use Autocom Independently vs. 1:1 Teacher/Student Contact	Educational Environment
	1a	1b	2a	2b	2c	3a	3b			
	Average Time Spent on A-C Before Taking a Break	Time Compared to Previous Method of Communication - Longer, Same or Shorter	Hrs/Day A-C Used	Approximate % of Classwork Completed with A-C	% of Time A-C Used for Classwork (vs. Other Use)	% of Time Spent for Other Uses Out of Total Time Used	Description of A-C's Use For Tasks Other Than Educational			
S_{CC} (portable)	1 hr	same amount	4	70%	90%	10%	-when not clear what student is trying to communicate -occasionally writes messages to entire class -artwork, makes designs & pictures w/ symbols	Group work (used in a multi-handicapped classroom & only one other child in the class could read)	Independently	Resource Special education room in public elementary school
S_{DC} (portable)	3-4 hrs	longer period	1½	80%	70%	30%	-takes it home weekends & spends about 4 hrs/day writing letters, messages, homework (1-2 letters/weekend) -plays tic-tac-toe on A-C -expresses opinions & makes comments	Short answers in which gestures can be used -not used during class period or group discussion, but for assignments & homework in study hall	Independently	Public High School resource special, education classroom
S_{KS}	1/3 hr	same amount	3/4	25%	100%	0%	None	-not advanced enough to use for sentences or social comments -not used in group situation	Uses it only with teacher	Residential Hospital School
S_{MG}	1/3 hr	longer period	2½	70%	95%	5%	-used very rarely when not clear what student is trying to communicate	-spelling is poor, so not able to use for social communication	Sometimes independently, sometimes needs teacher	Residential institution/hospital school for mentally retarded child
S_{LS} (portable)	1/3-½ hr	longer period	2	40%	50%	50%	-letter writing and conversation -when not sure what is trying to communicate -takes home occasionally	-group work -speech therapy -short answers where gestures can be used	Independently	Resource special education room in public elem school
S_{MM}	1 hr	longer period	1½	60%	95%	5%	-when not sure what is trying to communicate -takes it home occasionally for homework	-short answers in which gestures & oral communication can be used -group discussions	Independently	Residential hospital school
S_{TM}	3/4-1½ hrs	longer period	1-3/4	50%	95%	10%	-when not sure what is trying to communicate	-group work in which gestures & oral communication can be used	Independently	Self-contained special education classroom in public elem. school
S_{DW}	½ hr	longer period	1½	30%	100%	0%	None	-group work in which oral communication can be used -can't spell well enough to use A-C for anything other than classroom assignments	Sometimes independently, sometimes needs teacher	Self-contained special education classroom in public elem. school
S_{CR}	1/3-½ hr	same amount	½	50%	90%	10%	-occasionally when not clear what student is trying to communicate (gives a clue beginning letter) -speech therapy	-not used for other than classwork -group work or short answer requiring no written response. Other students in class can't read-easier & faster to use gestures in group	Sometimes independent, sometimes needs teacher	Public school day care program for young multi-handicapped children, housed in rural church facility
S=9		6 longer 3 same 0 shorter		$\bar{X}$ 63.8%	$\bar{X}$ 87.2%	$\bar{X}$ 13.3%	Other Uses -clarification of communication 7 -messages & conv. 3 -home use 3 -letter writing 2 -speech therapy 1 -art work 1	Not Used in -group work 9 -not able to use well enough for sentences messages or social communication 4 -short answers where gesturing or oral communication can be used 5	-independently 5 -independently & teacher asst. 3 -only with teacher asst. 1	

necessary for truly effective integration and program planning for these children.

For independent work, the aids were found to fit well into the classroom and generally were set up in a carrel or on a table. The aids, however, were found to lend themselves well to enhancing and encouraging classroom interaction. The stationary aids had to be set up to the side to avoid dangerous cords running across the floor. As a result, they tended to separate the children from the class. The portable aids did allow positioning anywhere in the room but there was no convenient way for the teacher to see the child's message without walking back to read his strip tape. Pre-positioning the children reduced these problems but future efforts at designing communication aids should take a closer look at these problems since a communication aid should facilitate interaction first and foremost.

5) Considerations for the Design of Future Aids

Two areas were identifed for future work in this area.

a) design/engineering/technology problems

b) communciation/interaction process problems

The first category is characterized by the physical design of the aids and is usually constrained by exisitng technology and costs. Among the items which are topics identified through this program were:

- a visible display
- a correctable display
- more flexible vocabulary
- more functional accessories
- size
- weight

- cost

In addition to these physical or design problems, a need for much more research was identified in the area of identifying or developing the most efficient communication processes or procedures for use with or by individuals who must communicate via this type of aid. Current techniques may provide independence, but are still quite slow and speed has been shown to be critical to communication and interaction opportunities for these children.

Evaluation Implementation Problems and Recommendations for Future Programs

In addition to the general results of the program, a special section of the project report was added to discuss the problems identified in the implementation of quantitative rate change evaluation programs with severely multiply handicapped children. Principle problem areas were identified and discussed and recommendations were made for the implementation of future research programs. The major problem areas dealt with are: 1) variability and drop-out/return of children; 2) irregularity and changes in educational programming; 3) evaluation measures; and 4) program implementation problems and procedures.

The discussion of guidelines for implementation of future programs includes items on the proximity of the field test centers, simple flexible research designs, simple data collection methods, restriction of subjects, problems in baseline periods, preparation for the program and teacher involvement procedures.

Summary and Conclusion

Overall results of the program indicate that independent communication aids can be of benefit to non-vocal severely physically handicapped children.

It was found that the aids in the classroom tended to facilitate the educational aspects more than the interactive communication aspects. This was traced both to specific shortcomings in these designs in the aids and to the restricted speed of communication that these aids are capable of providing at the present time. Educationally, the capabilities as cited by teachers as contributing the most to the facilitation of the educational process were: providing the opportunity to complete tasks independently, the elimination of costly hours of one-to-one instruction, and the opportunity for students to see and correct their own work. The major shortcomings identified were the lack of a visible correctable display on the portable aids, limited flexibility of the aids, and the still limited speed of communication of the children even when using the aids.

Results of this program are being used both as a basis for the design of future evaluation programs and for the continuing efforts in the area of communication aids and techniques for NVSPH children. Results of the program are being made available through the Trace Center, the ERIC System, and the government printing office. In addition, a paper is in preparation for publication based upon the evaluation program results.

PROJECT BRIEF

6. DEVELOPING AND IMPLEMENTING A COMPREHENSIVE STUDY OF COMMUNICATION AIDS AS THEY AFFECT EDUCATION AND COMMUNICATION SKILLS OF NON-VERBAL MOTOR-IMPAIRED CHILDREN

(Full report is located on page 293)

Introduction

This evaluation research program was designed to begin where the case study evaluation program left off and to obtain more quantitative information on the effect of communication aids, in general, on the development of communication and educational skills. Whereas previous programs directed attention more to qualitatively exploring the use of specific aids with children, the comprehensive evaluation program was to use a more rigorous evaluation design to obtain quantitative information that would be of a more generic type. Specifically, it was to be aimed at measuring the effect of these aids upon education and communication skills in a manner which would allow teachers, administrators and perhaps legislators to draw conclusions as to the cost efficiency or cost benefits of the aids. In addition, it was to provide more definition to teachers and researchers as to the specific areas which the aids facilitated and to provide some index of degree.

Objectives

The original objective of this project was to develop an evaluation design complete with measurement instruments and procedures in order to provide concise quantitative information on the effects of independent communication aids on the education, communication and language skill development of NVSPH children. This program was to pick up where the Autocom pilot field evaluation left off, and based upon the information and experience gained through that initial study, to develop as tight an evaluation design as could be carried out with non-vocal, severely multiply handicapped children. The initial planning and subject selection were to take place under this grant. The implementation of the evaluation was to be covered as part of a larger subsequent proposal. Close to the end of the first year of preparation, word was received that the larger subsequent grant, of which the comprehensive evaluation was a part, was not to be funded. An extension on the project was then requested and, in consultation with the BEH project officer, the objectives reformulated in order to maximize usable results from the terminated project. The revised objectives then became:

1) to develop a sourcebook for the implementation of evaluation programs for non-vocal communication aids
2) to document the preliminary work toward developing modifications for assessment materials for use with non-vocal, non-manipulative children
3) to prepare a report on the survey conducted to determine critical factors which should be covered in evaluating communication aids

Results and Use to be Made of Findings

The primary result of the project was a sourcebook titled "Developing and Implementing a Comprehensive Study of Communcation Aids as They Affect Education and Communication Skills of Non-Verbal Motor-Impaired Children." The sourcebook provides a review/discussion for conducting evaluation studies, research designs, selection of subjects, data collection techniques and data analysis procedures. In addition, it presents a model for implementing a comprehensive evaluation and a discussion of some techniques for modifying assessment tools for use with non-vocal, non-manipulative children.

The sourcebook begins with a discussion of reasons for conducting a comprehensive evaluation program. This discussion is based upon a survey taken of special educators, administrators, engineers, speech and language clinicians, physical therapists, occupational therapists and parents concerning factors which should be included in an evaluation of communication aids as aids to education and language development.

A discussion of potential research design follows and includes both a brief discussion of designs in general and specific descriptions of different research designs and their applicability to an evaluation program of this type with severely multiply handicapped children.

The discussion on subject selection is brief and seeks mainly to bring to the attention of potential researchers, the diverse variables which can affect the performance of these children and which must be controlled for or at least accounted for in the research design/procedures.

The section on data collection techniques describes some of the methods which were to have been used in the comprehensive evaluation and some techniques used in the previous Autocom pilot field evaluation. Examples of content items are presented along with practical implementation information obtained through experience with the techniques in previous evaluation programs.

Following the sections on methods and procedures, a model for implementation of a comprehensive evaluation is presented. The model makes use of several research designs to obtain both qualitative and quantitative information on the impact of the aid on the child's education and language development as well as information on techniques and procedures to maximize the benefit of the aid in the classroom both for the student and for the teacher.

Two other documents generated through the activities of this project are included as addendums to the sourcebook. The first is the report of the complete results of the survey used as the basis for the discussion of evaluation program objectives in section one of the sourcebook. The second is a report on the preliminary efforts toward adapting assessment material for use with non-vocal, non-manipulative children. Included in the report are discussions of techniques as well as specific examples of modified materials. The report is titled "Toward Developing a Diagnostic Battery of Basic Academic Skills for Non-Vocal Severely Physically Handicapped Children" reflecting the long range goal of the effort.

Dissemination

The overall results of this project are being disseminated through both cooperative interactions with other research groups in the field and through availability of the final reports from the Trace Center, the ERIC System, and the U.S. government. In addition, the results of the survey study on critical factors involved in evaluation of communication aids are being prepared for publication.

PROJECT BRIEF

7. PRELIMINARY LANGUAGE STUDY PROBES

Introduction

At present, investigators attempting to develop effective communication skills for the non-vocal severely physically handicapped individual are faced with a lack of research studies. There have been no systematic studies on language development processes in the non-speaking, non-manipulative, non-writing child primarily due to the problems involved in collecting appropriate data from these individuals. As a result, most attempts to develop communication programs for these children have primarily relied on the assumptions that normal language acquisition data can apply to the NVSPH child (e.g., that processes and sequences of linguistic maturation evidenced in the normal vocal and manipulative child can represent the linguistic maturation of a non-vocal, non-writing, non-manipulative child). Recent literature, however, has revealed that there may be qualitative and/or quantitative differences between the processes involved in linguistic maturation of the normal child and that of other populations (Yoder & Miller, 1972; Miller, 1975).

In light of this, thorough investigation is needed before teachers and clinicians can adopt the normal language acquisition (NLA) as a basis for the development of communication intervention programs for the NVSPH child as well as for a model of the development of language in all children.

Most of the research which has investigated communication and language function in the NVSPH child has been cursory and speculative. This is due primarily to severe problems involved in gathering a sufficient language data base from which to study these children's language production. In the past, the only way to secure a language core would be to write down the childrens' "utterances" as they were pointed out on the communication board of some sort. This method is not only extremely time-consuming and tedious, but also allows for inadvertent interpretation and modification in cuing on the part of the transcriber. More recently, communication aids have been developed which provide a means of printed output. With these communication aids, for the first time, researchers can begin to study the production of the children totally independent of any transcriber. The purpose of this study was to initiate a program to study the language development processes of non-vocal severely physically handicapped individuals using such independent communication aids.

Objectives

The objective of this study was to begin the exploration into the language development patterns of non-vocal physically handicapped adolescents by conducting some initial exploratory probes. The study focused on three questions:

1) How does the NVSPH child develop language and how might this be related to the development of language processes evidenced in the normal child?

2) What vocabulary elements or words are used by the NVSPH child or adolescent who is a) learning to communicate and b) provided with more effective means to communicate after having a manual communication board for some time?

3) How can a communication aid enable an educator to better assess NVSPH child's linguistic ability and performance?

Procedures

The communication aid used by the students in this study was the portable Autocom. The subjects were three non-vocal severely physically handicapped adolescents who already had independent communication aids. These are the same three portable Autocom users described in the case study evaluation program earlier. A profile of the three subjects is provided in Table 7.

At the beginning of the study, the students were administered a battery of language tests and conceptual development tests. These tests include the assessment of language comprehension (ACLA), the Miller-Yoder Test of Grammatical Comprehension (MY) and the Boehm Test of Basic Concepts (BEOHM). In addition to these formal assessment measures, a language sample of approximately 50 utterances was obtained and analyzed. Throughout the evaluation period of five months, data were collected through the following procedures:

1) A permanent record of all of the subjects expressive output was obtained by collecting the thermal print tape which was the output of the communication aid
2) Periodic five minute language samples and accompanying information pertaining to the educational and communicative environment at the time of the sample were obtained
3) Information gathered through teacher questionnaire forms and interviews
4) Formal and informal assessment measures

Results and Use to be Made of Findings

Table 8 illustrates results obtained from the assessment procedures. Because all of the subjects scored nearly perfectly on the BOEHM, the Miller-Yoder and the Children's Language Comprehension Tests, it was felt that further testing and comparison would be of little value and this testing

Table 7.

Profile of Three Subjects

Subject	Age as of 9/73	Sex	Neurological* Description	Previous Communication Method (Prior to Autocom)	Date Receiving Autocom
S_{DC}	19	F	Primarily athetoid, some spasticity on left side, quadraplegic	Language board, gestures with eyes and pointing	4/73
S_{CC}	14	M	Athetoid, quadraplegic Wristcock	Gestures (tried typewriter, but could not use)	12/20/74
S_{LS}	14	M	Athetoid, quadraplegic	Letter board, gestures	3/20/72

*Provided through a neurological and neuropsychological evaluation conducted by Dr. Raymond Chun and Dr. Charles Matthews, University Hospitals, Madison, Wisconsin.

TABLE 8

Assessment Results

Name	TTR*		Completed Sentences / Sentence Attempts in TTR		Boehm	MY	ACLC 5/74**				# of Months Using A/C as of 5/74
	5/74	9/74	5/74	9/74	5/74	5/74	A	B	C	D	
S_{LS}	.61	.66	16/16	16/18	45 (90%)	83 (90%)	100%	100%	100%	100%	23
S_{CC}	.55	.50	7/14	5/15	50 (100%)	82 (97%)	100%	100%	100%	100%	5
S_{DC}	.61	.69	13/14	13/13	50 (100%)	84 (100%)	100%	100%	100%	100%	11

*Based on 100 word samples (Type/Token Ratio)

**With the ACLC, the child is tested on the following:

A. Vocabulary
B. Discrimination of a sentence given two critical elements
C. Discrimination of a sentence given three critical elements
D. Discrimination of a sentence given four critical elements

was dropped from the study.

The language sample taken from the daily tape output of the three NVSPH students during the same periods that the tests were administered varied in content and prose style from the test results to such a degree as to indicate that the test scores were not able to accurately predict performance for individuals of this age. The following written examples illustrate variances of output by the three students:

Scc: "I saying I am girl and the 8 brat."
"I mov in nout hout."

Sdc: "We will go but people will come there and we will go home."
"I think the letters will help people to talk to me now."

Sls: "What book am I getting next."
"I was thinking I would go up to the IMC and get some records."

Developmental sentence scoring (DDS), a procedure developed by Lee (1974) was chosen as the measure for syntactic analysis. The results of these syntactic analyses are presented in Table 9 and Table 10. Again, based on a comparison of the children's written output and the scores of the DDS, questions are raised about the appropriateness of this measure in drawing conclusions about the competencies of these children (see Table 10). Of particular concern was the effect of communication through a slow written medium upon the syntactic structures chosen for construction of messages.

In addition to the syntactic probes, a comparison of the word frequency count for the NVSPH individuals was made to word frequency counts made on normal adults. The NVSPH average sample was of everyday conversation by NVSPH individuals whose average age was 15.7 years.

TABLE 9

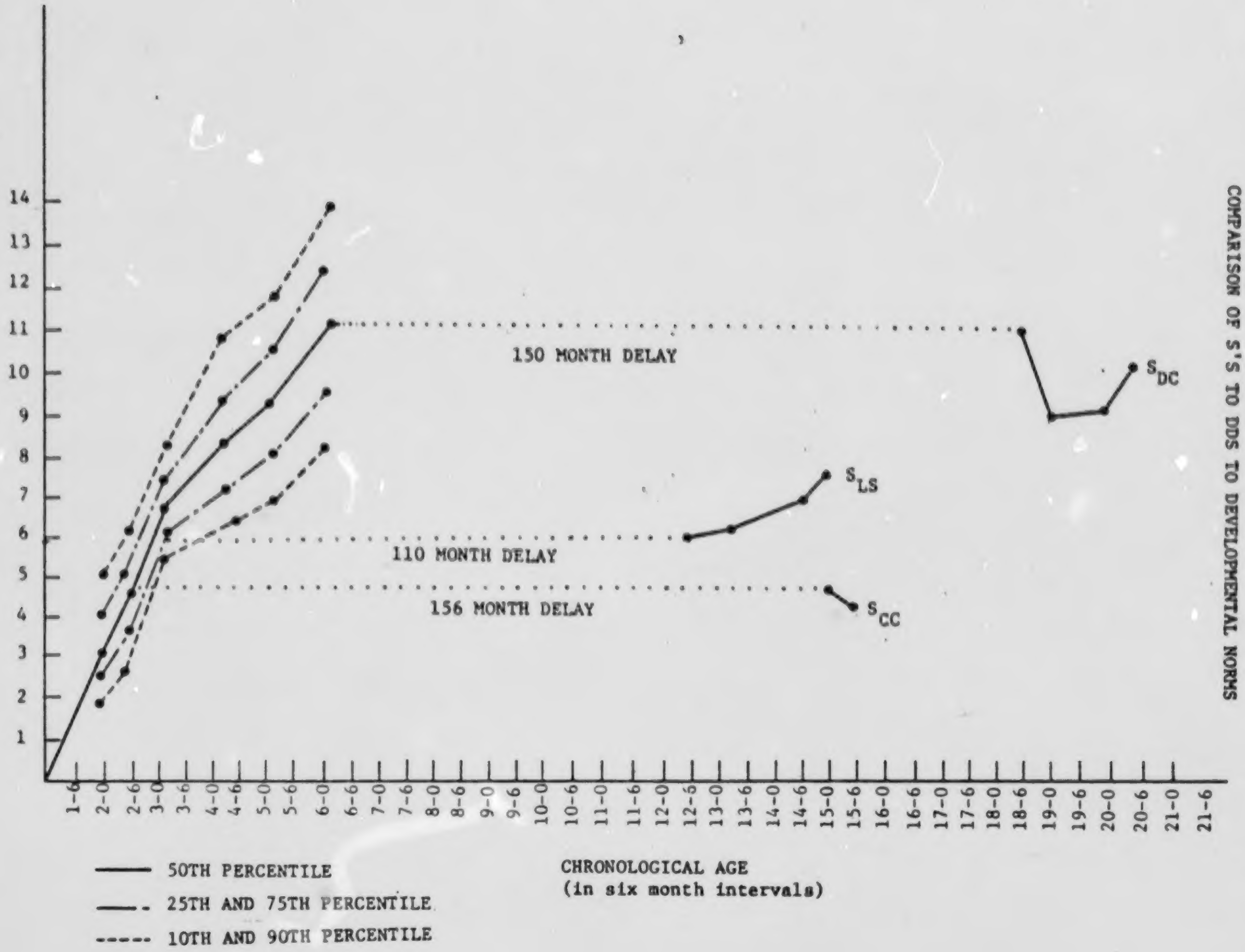
DEVELOPMENTAL SENTENCE SCORING

	Pre AC			Just After Receiving AC			May 1974			Sept. 1974		
Name	N	DDS	Age	N	DDS	Age	N	DDS	Age	N	DDS	Age
S_{LS}	51	5.86	12-11	18	6.05	13-8	52	6.78	15-2	51	7.43	15-6
S_{CC}[1]	--	--	--	--	--	--	50	4.66	15-6	50	4.21	15-10
S_{DC}	19	10.94	19-0	50	8.76	19-6	50	8.9	20-7	53	10.24	20-11

[1] Data was obtained in periods 1 or 2 for S_{CC}. S_{CC} had only yes/no communication prior to receiving the Autocom. During period 2, just after receiving the Autocom, S_{CC}'s language samples were recorded as the teacher's interpretations of S_{CC}'s sentence and not his actual output.

TABLE 10

COMPARISON OF S'S TO DDS TO DEVELOPMENTAL NORMS



The adult language sample was based upon the Jones, Wepman word count taken of older adults discussing picture cards. Results showed approximately 42% common words at the top 50, 100 and 200 word levels. 80% of the top 50 words used by the NVSPH individuals were in the top 200 of the "normal adult." (See Table 11). As expected, "verbs" and "conjunctions" and "other" words were more common in the high frequency lists than were nouns and modifiers (Table 12). Of more general interest than the statistics, though, is the information that can be gathered through examination of the summary of the wordlist in Table 13. These results are currently limited by the small language sample that was obtainable due to hand transcription techniques.

More definitive studies are under way using a larger data base and more detailed and controlled comparisons. These and other informal examinations of the production data revealed several problems and very critical concerns which need to be addressed before an investigation of language development in the NVSPH child can be effectively initiated. Methods for assessing linguistic competence should be more appropriate to the NVSPH child. Formal assessments which have been developed and normed on normal manipulative ambulatory and vocal children may have little value in exploring the language development of the NVSPH child. It, therefore, appears that informal techniques will need to be developed for this purpose. Most current informal techniques are syntactically based, however, and semantically based analyses appear to be more appropriate to the test in the investigation that was under discussion. An extensive review and exploration of linguistic assessment techniques which are more semantically based or functionally based are needed prior to further investigation into language developmental processes in this population..

TABLE 11: Summary of Comparison of First 50 NVSPH Word List to Large Portions of "Normal Adult" Word List

COMMON	%
21	42% of top 50 words of both lists were common
47	47% of top 100 words of both lists were common
84	42% of top 200 words of both lists were common
36	72% of top 50 NVSPH words in top 100 nonoral
70	70% of top 100 NVSPH words in top 200 nonoral
41	82% of top 50 NVSPH words in top 200 nonoral

TABLE 12
'MOST FREQUENT WORDS' COMPARISON
ADULT NORMAL INDIV. (JONES-WEPMAN)
VS.
NVSPH ADOLESCENT INDIV. (HARRIS-VANDERHEIDEN)

	MOST FREQUENT WORDS COMP.	Nouns	Verbs	Modifiers	Conj.	Other	Total
1.	words common to top 100 words of both	11	21	1	2	12	47
2.	% of 47 common words in each category	23%	45%	2%	4%	26%	100%

	BREAKDOWN OF JW NORMAL ADULT WORDS	Nouns	Verbs	Modifiers	Conj.	Other	Total
3.	# of top 100 in each category	26	31	14	8	21	100
4.	% of top 100 in each category	26%	31%	14%	8%	21%	100%

	BREAKDOWN OF NVSPH WORDS	Nouns	Verbs	Modifiers	Conj.	Other	Total
5.	# of top 100 in each category	36	35	10	2	17	100
6.	% of top 100 in each category	36%	35%	10%	2%	17%	100%
7.	% of JW Normal Adult words in each category that was common (% = $\frac{\text{common}}{\text{JW category total}}$)	$\frac{11}{26}$=42%	$\frac{21}{31}$=67%	$\frac{1}{14}$=7%	$\frac{2}{8}$=25%	$\frac{12}{21}$=57%	$\frac{47}{100}$=47%
8.	% of NVSPH words in each category which were common (% = $\frac{\text{common}}{\text{NSVSPH total}}$)	$\frac{11}{36}$=30%	$\frac{21}{35}$=60%	$\frac{1}{10}$=10%	$\frac{2}{2}$=100%	$\frac{12}{17}$=70%	$\frac{47}{100}$=47%
9.	Mean % of words in each category which were common ($\frac{\text{common words}}{\text{1/2 (JW wds + NVSPH wds}}$)	35%	64%	8%	40%	63%	47%

1. Jones-Wepman (1966)
2. Harris-Vanderheiden

Table 13

WORD FREQUENCY LIST[1]

BY FREQUENCY

WORDLIST II MARKED

Words which appeared more than once in the total sample of 3892 words are listed in the order of frequency with which they occurred.

	I	248		#	come	19			day	10
#	is	248		##	hurt	19			Friday	10
#	to	103			Mr. Caswell	18			they	10
#	and	97		##	know	17		##	tomorrow	10
#	the	83		#	think	17			don't	9
#	it	82		#	want	17			Madison	9
#	you	57		##	love	16			portable	8
	a	52			this	16			red	8
#	I'm	49		#	will	16			talk	8
#	me	40		##	would	16		##	thanks	8
#	my	40		#	give	15		##	today	8
#	in	38			going	15		##	when	8
#	have	37			mom	15		##	where	8
#	go	35			we	15			your	8
##	good	35			of	13		##	feel	7
#	are	31			at	12			Gregg	7
#	see	30			Dad	12			had	7
#	like	29		##	eat	12			he	7
#	for	28		##	get	12			home	7
#	on	28			got	12			hot	7
#	not	26			Auto-Com	11			Jill	7
	am	25		##	bathroom	11		##	make	7
#	now	25			be	11			man	7
#	that	25			camp	11			movie	7
#	do	24			dear	11			ok	7
##	because	23		##	friend	11			people	7
#	can	22			Jack	11			school	7
#	how	22		##	play	11			all	6
##	what	22		##	some	11			back	6
#	with	22		##	take	11			board	6
	hi	21			went	11	2113		bring	6
##	please	21		##	about	10	54%		children	6
##	look	20	1668		CPCG	10			daughter	6
			43%							

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

---

[1] It should be noted that words which were misspelled were included in the word frequency count, if it could be determined that the child understood correct use of the word by looking at the context in which he used the word.

	Debbi	6
	fun	6
	girl	6
	happy birthday	6
	having	6
	hope	6
	independent	6
	life	6
	our	6
	parents	6
	picture	6
	she	6
	TV	6
	watched	6
	year	6
	around	5
	ate	5
	bar	5
	beautiful	5
	communicate	5
	counselor	5
	dorm	5
	from	5
	handicapped	5
	Harold	5
	Lydell	5
	move	5
	nut	5
##	repeat	5
	sometimes	5
##	sorry	5
##	stop	5
	tape	5
	very	5
	before	4
	building	4
	bingo	4
	boy	4
	but	4
	by	4
	Craig	4
	can't	4
	did	4
##	every	4
	Gompers	4
	guess	4
	hate	4
	him	4
	if	4
	mean	4
	miss	4
##	more	4
	out	4
	saw	4
	Sunday	4
	Wendt	4
	wheelchair	4
##	why	4
	wish	4
	Wordmaster	4
	writing	4
	act	3
	algebra	3
	aware	3
	cabin	3
	classes	3
	close	3
	could	3
	Daddy	3
	different	3
	director	3
	doctor	3
	dog	3
	doing	3
	exam	3
	everyone	3
	everywhere	3
	getting	3
	glad	3
	good	3
	group	3
	heel	3
	here	3
	house	3
	lake	3
	legs	3
	letter	3
	mad	3
	mail	3
	many	3
	mark	3
	marry	3
	may	3
	maybe	3
	much	3
	name	3
	need	3
	no	3
	old	3
	outside	3
	remember	3
	rest	3
	sew	3
	show	3
	sick	3
	something	3
	try	3
	until	3
	used	3
	well	3
	alot	2
	ask	2
	child	2
	Creer	2
	CP	2
	dumb	2
	end	2
	expect	2
	fair	2
	fast	2
	father	2
	film	2
	find	2
	first	2
	fish	2
	free	2
	graduate	2
	happen	2
	hard	2
	higher	2
	home ec	2
	ice	2
	it's	2
	last	2
	little	2
	listened	2
	lunches	2
	midnight	2
	morning	2
	mostly	2
	mother	2
	newspaper	2
	next	2
	night	2
	note	2
	one	2
	pat	2
	pig	2
	place	2

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

pop	2
pot	2
put	2
radio	2
received	2
respond	2
sack	2
said	2
sing	2
so	2
soft	2
speech	2
steak	2
store	2
sun	2
swimming	2
table	2
tell	2
there	2
together	2
too	2
ugly	2
use	2
while	2
without	2

A second concern involves data collection procedures. Toward this end, a new datarecording unit was developed as a part of this study. The data-recovery technique utilizes a miniature datarecorder which is contained directly within the communication aid and permits recording of up to 50,000 characters on a tape cartridge approximately the size of a matchbook. Since this recorder also places timing marks on the tape, the researchers will be able to construct complete records of the children's total utterances along with time references which can be used to correlate data with textual information and to conduct studies on communication frequency and rate. Since the output of the recorder is directly computer compatible, this technique also greatly simplifies data reduction by eliminating all transcription and computer entry steps. Researchers, then, can call up any section of the data for hand analysis or can program some analyses to be conducted directly by the computer. Table 14 lists some of the datarecorder information which could be provided to the researchers by the computer.

Based on observations during the pilot explorations, it appeared that the NVSPH children acquired linguistic competence prior to having an effective means of communication and, when given such a means for communication, were able to "transfer" this knowledge to a production mode and rapidly acquire English syntax. This was particularly noted in Scc. Research into this hypothesis should be implemented through an assessment of the child's comprehension skills prior to utilizing effective means of production and after they are provided with communication aids which give them effective production channels. Additional analyses should be made of the children's production syntax as they develop communication skills

TABLE 14

Samples of Data Recorder Information Which Could be Provided by a Computer

1. Words most frequently used by the child and type-token rations
2. Sentences with which these words most frequently appear
3. Amount and ratio of the child's expressive communication as measured over time
4. Average length of words used by the child as measured over time
5. Average length of the child's phrases and/or sentences as measured over time
6. Grammatical and syntactical structure of the sentences expressed by the child
7. Complete transcription of the child's expressive communication and ability to reconstruct at any time the child's total expressive communication (exclusive of communications sensed by the child)
8. Time sample of tests communication which can be correlated with information from video and audio-recordings pertaining to the concurrent linguistic environment and communication interaction

using the communication aid. Concurrent exploration should also be made into:

1) the grammar evidenced in the children's production syntax
2) the content of their production (and underlying semantic notions)
3) the functions of the children's communication
4) the relation of function and immediacy of communication to the production syntax used by the children
5) the variations in syntax, semantics and function of their communication in different communicative interaction situations

The most significant results of this initial study were the delineation of some of the constraints in studying language development in these children and the development of more comprehensive data acquisition procedures. The continuation of these studies will initially benefit those working on developing vocabulary systems for use with individuals communicating through closed vocabulary systems (e.g., work boards). Later uses will include development of better assessment measures and eventually, the development of more effective language intervention and communication development programs.

SECTION III

PROJECT DOCUMENTATION

FORMATIVE EVALUATION/DESIGN OF A LOW-COST SCANNING AID

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June, 1976

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I. STATEMENT OF THE PROBLEM

Many non-vocal severely handicapped (NVSH) children can be provided with effective means of communication through the use of a communication board. To utilize this method, the child points sequentially to message elements in order to convey his thoughts and ideas. There are many different types of communication boards and the child need not have fine manipulative skills to use them. Successful operation does, however, require pointing skill of some degree. If a child is unable to point (with head or hand) it may then be necessary to look at other techniques for allowing him to indicate the elements of his message.

One very simple and common approach to use with these non-pointing children is the scanning approach. With this approach, a person or aid presents the various symbols or words to a child who essentially remains passive until the correct item is presented. At this point, the child would make some kind of signal indicating that the correct item had been presented. In other words, the person or aid scans over the various choices until the child responds indicating that the correct choice has been reached. Thus, the term, "scanning" approach.

The simplest example of a scanning technique is the yes-no guessing game. Here, a person trying to communicate with a child, presents a child with choices, one at a time, and the child nods "yes" when (and if) the second person reaches the desired message (Figure 1A). Another example of a scanning technique (Figure 1B) would be a second person pointing individually to pictures, words or letters on a communication board. Here again, the child would respond to the second person by nodding or making some signal "yes" when the person points to the correct element of the child's message.

Scanning techniques are quite effective as communication methods for children who are severely limited in voluntary physical control. The only requirement for use of techniques in this category is that the child has some consistent and reliable response. This response may be produced through knee, foot or head movement or even such low effort movements as eye blinks or contractions of a single muscle.

There are a number of different types of scanning aids which have been developed. Some involve scanning the alphabet and typing out responses on typewriters or other printing mechanisms, while others are portable letter scanners with strip printers. Some indicate letters or words through back lighting or illuminating an area around the letter, while others use small light emitting diodes (LEDS) placed near the symbols.

Most of these aids, however, are expensive and/or were not well designed for the mentally retarded individual. No low-cost flexible aids were available for the young or mentally retarded child.* A simple

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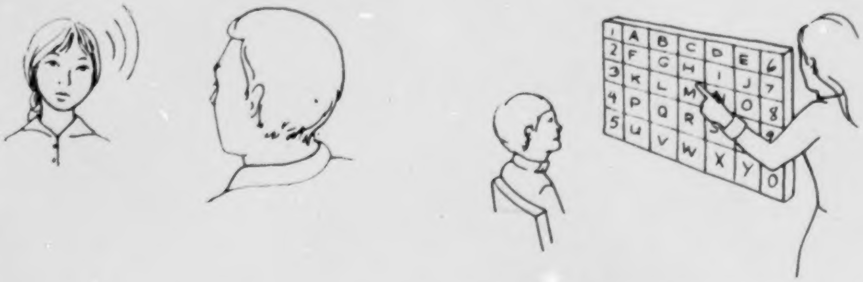
*This describes the state of the field when the program began. Simple aids have been developed since that time in addition to those described herein. The applicability of some of these to the severely mentally retarded, however, has yet to be determined.


1 A B C D E 6
2 F G H I J 7
3 K L M N O 8
4 P Q R S 9
5 U V W X Y 0

A. Yes/No Guessing B. Manual Scanning

FIGURE 1

YES/NO GUESSING AND MANUAL SCANNING

low-cost rotating pointer aid called the "Rotocom" was, therefore, developed at the Trace Center.

II. THE ROTOCOM

The Rotocom is a simple pointing aid for children or adults who are not able to point for themselves. The aid has a rotating pointer which can be started and stopped by the handicapped individual using a switch (see Figure 2). The aid is designed so that cards containing letters, words, pictures or messages can usually be slipped behind the pointer. Pre-printed cards can be used or the teacher/clinician/parent can make his/her own card from stiff paper or cardboard and a marking pen. To operate the aid, the user hits or touches a switch once. The pointer will then rotate until the user hits the switch again, stopping the pointer on the desired picture, word, phrase, etc. An alternate mode of operation would be to have the pointer rotate as long as the switch is held down. This mode of operation, however, is difficult for many severely handicapped individuals, particularly those with cerebral palsy.

The Rotocom can be used with any type of momentary switch and can thus be adapted for use with a wide range of individuals. The particular switch to be used with an individual would be chosen to match his particular abilities. Some examples of the many types of switches that could be used are shown in Figure 3.

In addition to being used as a communication aid, the Rotocom can also be used as a simple pointing aid for use in assessment procedures. When used as a communication aid, a card with letters, pictures, words or other message units is inserted behind the pointer. When used as an assessment aid,multiple choice cards can be made up and inserted behind the pointer. The child can then use the pointer to select the appropriate item (see Figure 4).

Preliminary field testing of the aid provided a very favorable response. The construction techniques used in the original prototypes, however, did not lend themselves to low-cost production. A re-design was therefore warranted to minimize the cost and to maximize its flexibility. Further field testing of the aid was also indicated.

III. OBJECTIVES OF THIS PROJECT

A. Original Objectives of the Project

The original objectives of this project were to do a field test on the Rotocom and to re-design the Rotocom into a low cost and easily reproducible form. While conducting the field test on the Rotocom, however, a second approach for providing a very simple means of indication to young and mentally retarded children was presented by the teachers and clinicians working with the Rotocom. Some advantages were then pointed

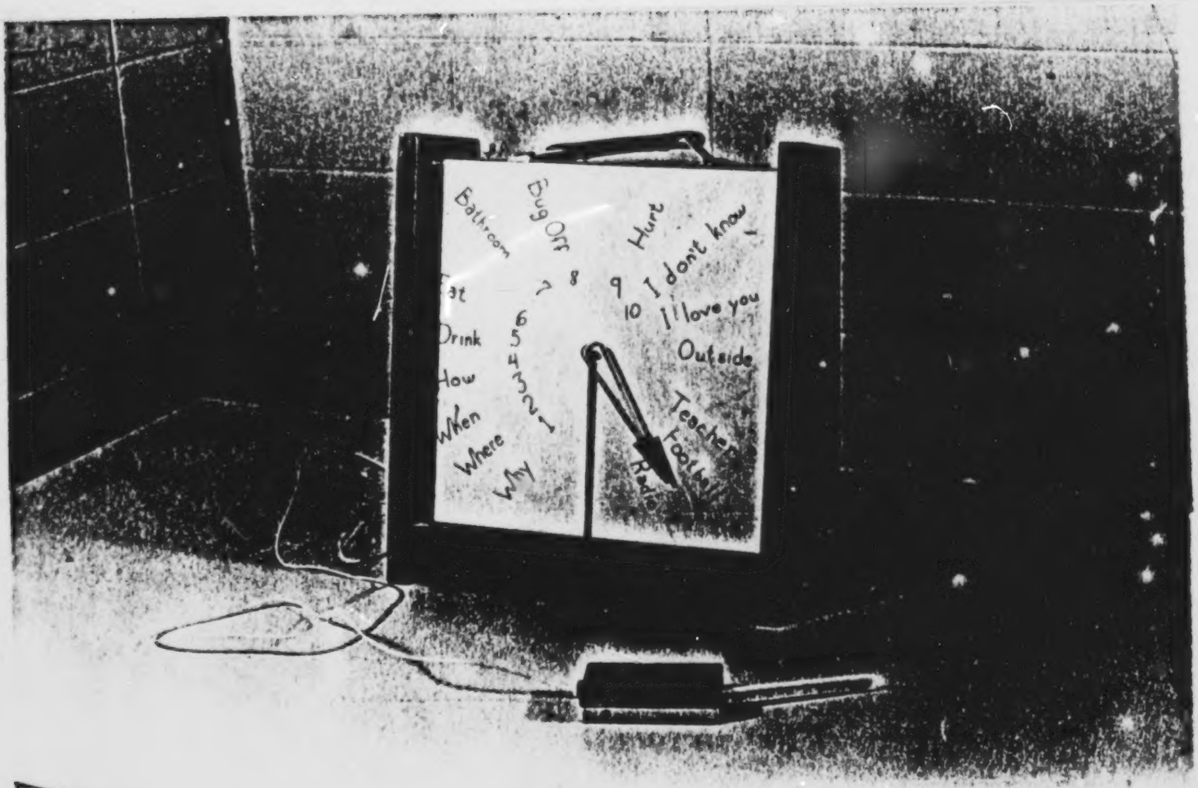
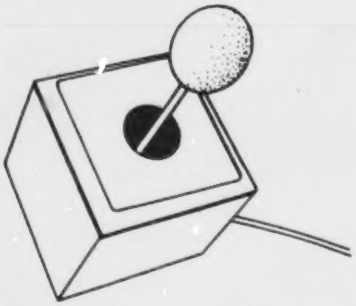
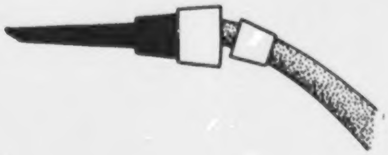

Bathroom
Bug Off
Hurt
I don't know
I love you
Outside
Teacher
Football
Radio
Why
Where
When
How
Drink
Eat
1
2
3
4
5
6
7
8
9
10

FIGURE 2

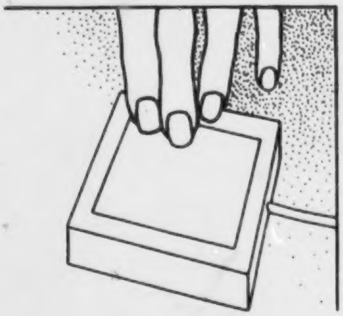
Rotocom



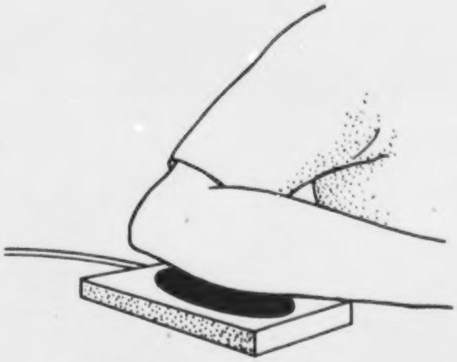
WOBBLE STICK
This switch can be operated by bumping the stick in any direction.



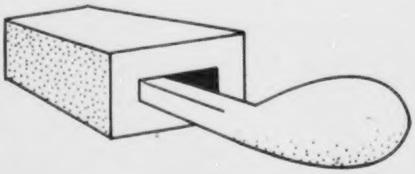
PUFF AND SIP
Fine breath control is all that is needed to operate this type of switch.



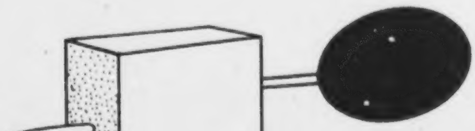
IMPACT SWITCH
Operated by a hard pounding, or soft touch.



PROXIMITY SWITCH
is operated by holding a part of the body, such as the elbow, near the switch.



PADDLE SWITCH
for lateral hand motion, or foot motion.



BREATH SWITCH
A sensitive switch operated by a puff of air or very light touch.

FIGURE 3

Types of Switches

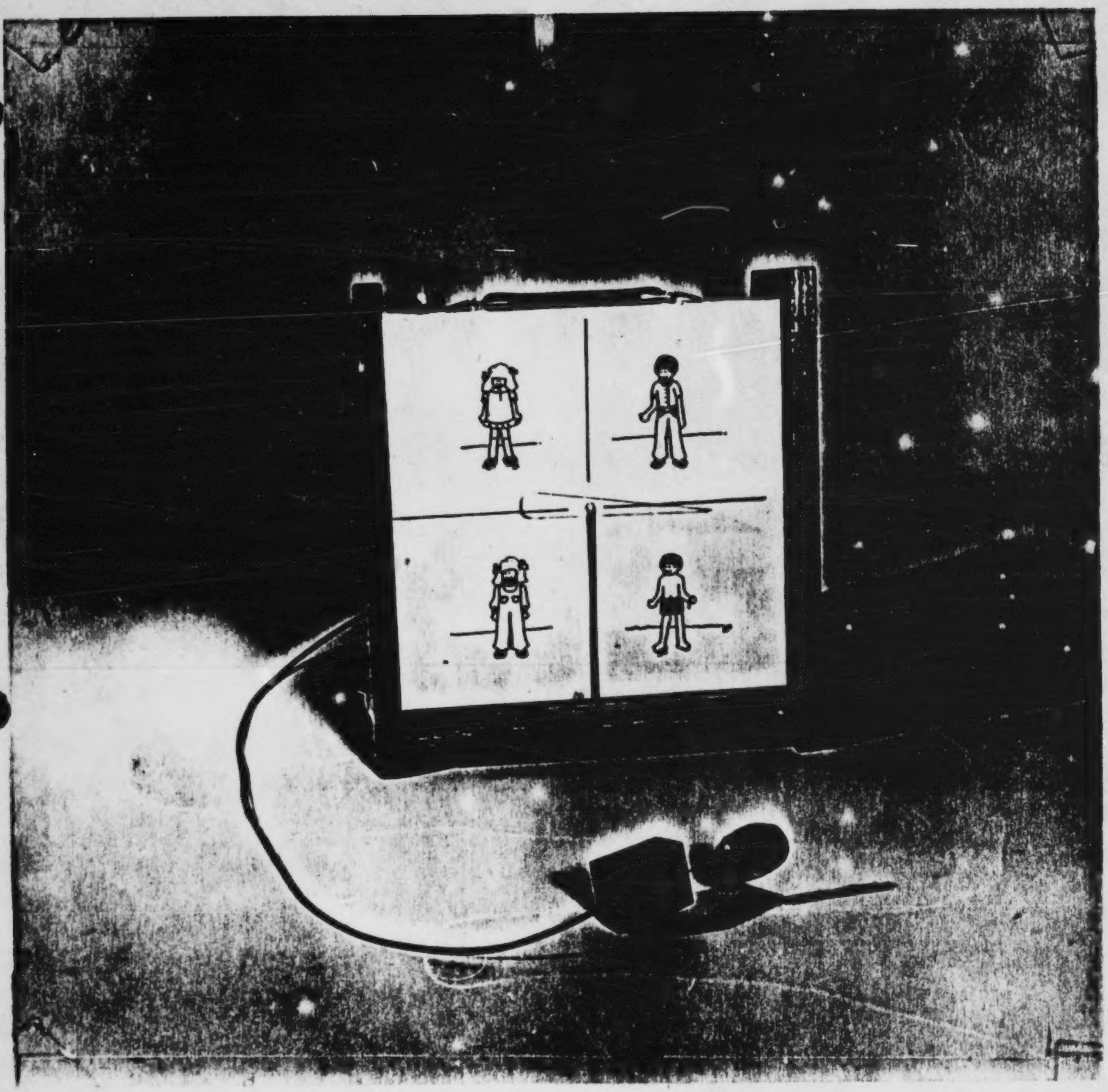


FIGURE 4

Rotocom with Evaluation Display-M.Y. Test

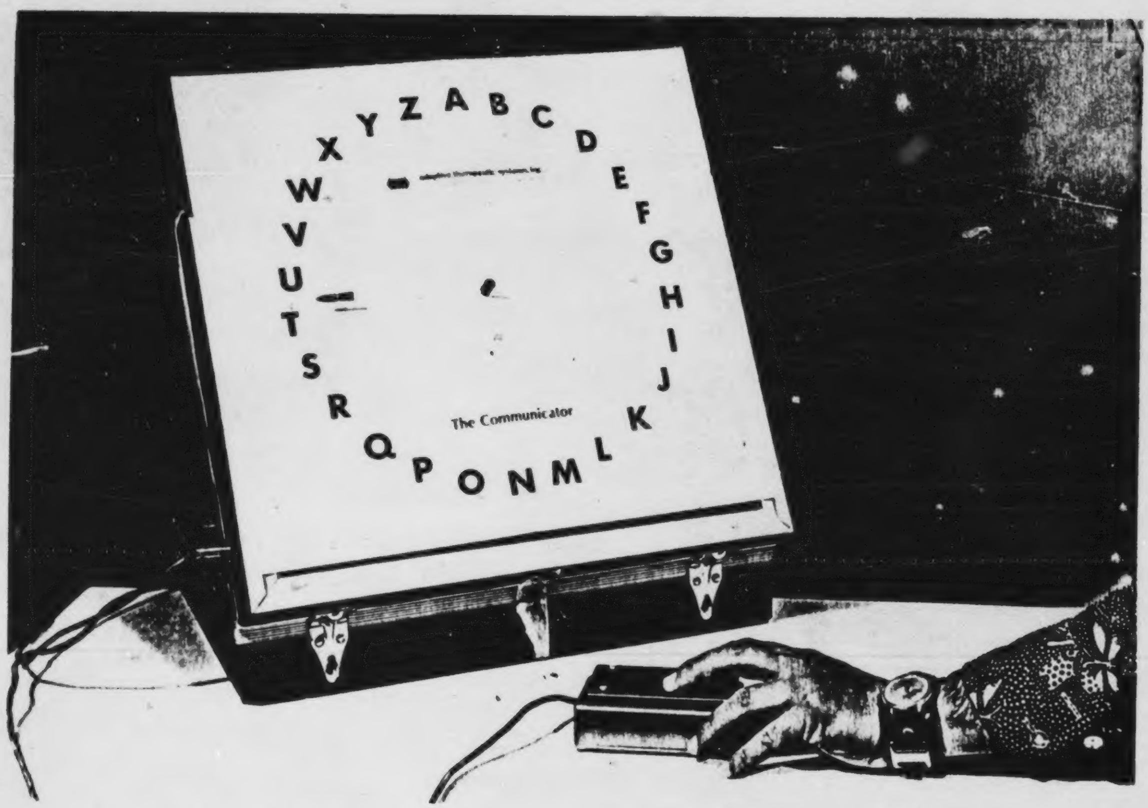
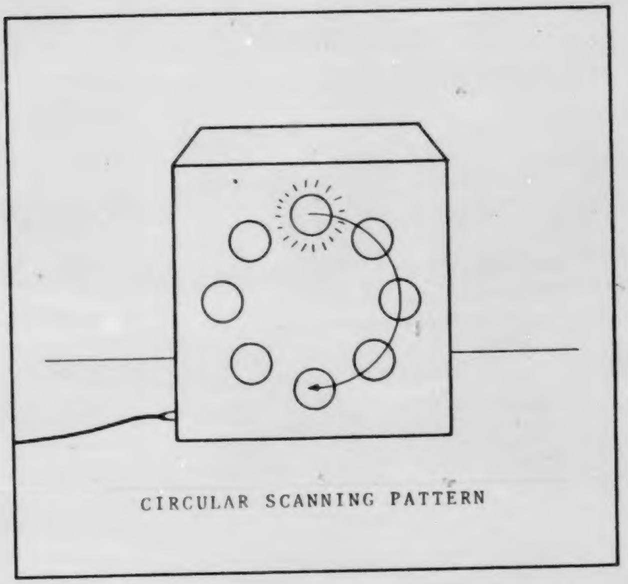

XYZABCDEFGHIJKLMNOPQRSTUVW
The Communicator

FIGURE 5

Communicator

(Adaptive Therapeutics, Inc.)



CIRCULAR SCANNING PATTERN

FIGURE 6

at several things at once. First he would look at the display and find the item he wanted. He would then have to fixate on it and also on the moving pointer, waiting for the pointer to come around to it before he would have to then hit the switch. For low level children, they also thought that the idea of pointing may not be as straightforward as actually lighting up the square containing the desired element. In addition, they had concerns that the moving pointer simply because of its motion, would tend to capture the attention of the handicapped individual, interfering with his ability to search the display for the desired element. Exactly how this type of interference would compare with the interference which would be caused by a jumping light is not certain and is something that will be examined in the comparative evaluation. The therapists, however, thought that the moving light would present less of a distraction and would be more obvious to the young or mentally handicapped child than would be the rotating pointer. One suggestion which was made which might reduce the effect of the jumping light would be to have one square extinguishing slowly as the next square was lighting. As a result, the squares would look more like the light was shifting from one cell to the next rather than like it had suddently jumped. Although this is electrically more complex, it is also a technique which should and will be explored.

B. Criteria for Design of Alternate Approach

Through consultation with the field clinicians and researchers, the following criteria were determined for the design of the simple scanning aids. In reviewing these criteria it is important to remember that the objective of this design program was to develop a very simple communication aid which could be used as a first communication initiation tool for young and mentally retarded children and not as a long-term communication aid for the advancing child.

Essential features:

- ability to be used by mentally retarded children
- variable speed control
- backlit illumination of the display
- low cost
- flexible display that can be easily changed
- simple display (not visually confusing)
- sturdy, durable, and reliable

Highly desirable features:

- fully portable (battery operated)
- bi-directional display which can be used from front or rear of the aid (to allow the clinician to face the child when communicating)
- child would be able to turn aid on and off
- flexible interfacing system to allow the aid to be used by individuals with a wide variety of physical handicaps

Other desirable features:

- variable resolution (would enable the aid to change from 4 to 16 selection squares)
- beep or buzz for calling for help or attention
- operable in sunlight and out-of-doors
- wheelchair mountable
- bed mountable
- self-packaging (would fold into a convenient carrying package)
- size and location of aid would promote eye contact between child and others
- reversible scan ability
- expandable to independent aid (printer or other display could be hooked up to the aid)
- versatility and mode of operation (the aid would be able to operate in different types of scanning modes)

C. Design Considerations

1. *Number of Selections (Resolutions)*

One of the initial design considerations that had to be made was the number of selection choices that would be on the face of the aid. For children just starting out, a very low number such as four was seen as being most desirable. However, a simple 4-selection aid would probably only be useful for a very limited amount of time, therefore the child would be ready for a larger number of items. It therefore seems that the aid should be able to operate with as few as four selection choices, but that it would be much more flexible if it were able to expand to provide a larger number of selections as the child developed. An upper limit of approximately 12 - 16 choices was determined as being sufficient for this type of communication initiation and training aid. Once the aid had reached this level, the child could then move on to more advanced types of aids.

This is a problem that does not come up with a rotating pointer since any number of choices can be arranged around the circle circumscribed by the pointer. When using this type of aid, however, only a discrete number of different choice patterns is possible such as 4, 8 and 12.

2. *Illumination or Indication of the Square*

Several different techniques were explored for indicating the various selection squares. Basically, these techniques can be broken down into four categories:

1. corner lighting indication
2. edge lighting indication
3. spot back lighting indication
4. full back lighting indication

Corner Lighting Indication

With this approach, a small indication lamp is placed in the corner of the display squares (see Figure 7. A square is then selected whenever the corner light is lit. This approach has a couple of practical advantages. First of all, it allows opaque pictures to be easily used with the aid. Any picture, card, etc. which does not cover the corner of the square can be used with this approach. In contrast, the back lighting approaches require that the picture be transparent or translucent. The other advantage of this approach is that very low power solid state lamps (LED's) can be used as the corner light. These LED's essentially never burn out and also lend themselves well to battery-powered aids.

Edge Lighting Indication

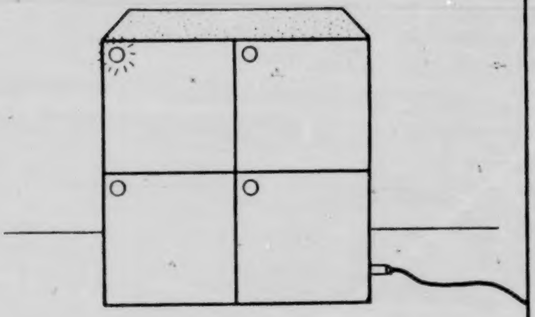
With this approach, the entire border is lit up around the desired square (Figure 8). This approach also has the advantage of allowing opaque cards and pictures to be easily used with the aid. It also has the potential for being implemented using light emitting diodes. It is slightly more complicated to construct but was thought to have some advantages over the corner light approach in terms of clearly indicating the chosen square.

Spot Back Lighting Indication

With the spot back lighting approach, a small lamp is put directly behind each of the squares. A transparent or translucent picture would then be placed or drawn on each of the squares. When the small lamp behind the square was illuminated, it would create a bright spot in the middle of the picture, drawing, etc. (see Figure 9). This technique could be implemented with an LED, or with a small conventional light bulb such as a miniature version of a flashlight type bulb. If an LED were used, one would have the same advantages of long life discussed above. The LED's in general, however, have a difficult time putting out enough light to be seen in daylight. Even the light bulb, however, has difficulty being seen in direct daylight unless it is drawing a considerable amount of power. The major advantage to this approach was seen to be a more direct indication of the picture, drawing, etc.

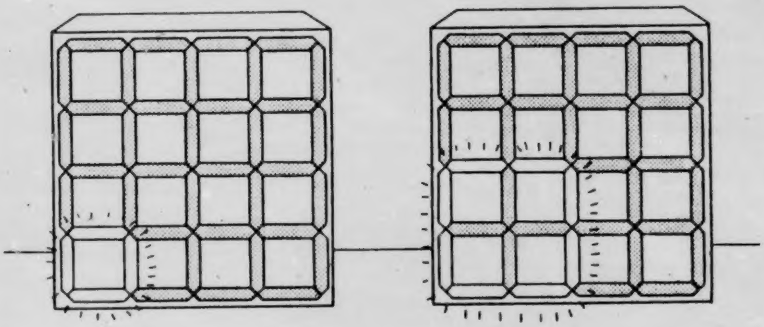
Full Back Lighting Indication

The final approach is to completely light up the square which is being indicated (see Figure 10. This approach is probably the most straightforward and obvious means of indication and provides the child with a very fair indication of the indicated item. This technique, however, requires the use of a conventional light bulb since the LED's do not give off enough light to illuminate an entire square. This technique also draws quite a bit of power requiring a larger battery supply than the other approaches. Again, with this technique the pictures must be either transparent or translucent unless they are drawn directly on the communication aid.



CORNER LIGHT INDICATION

FIGURE 7



BORDER LIGHTING

FIGURE 8

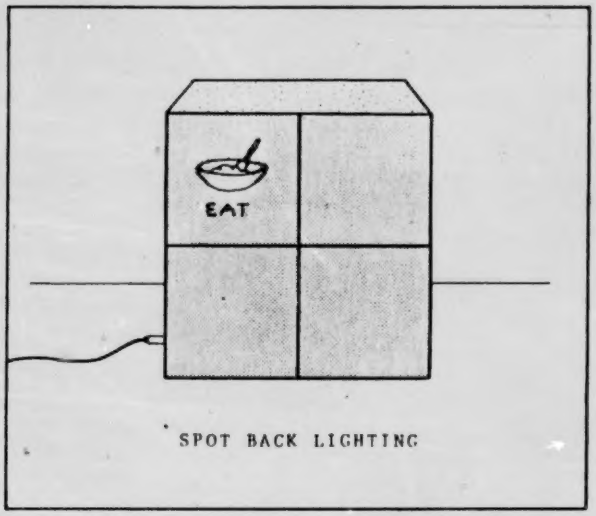

EAT
SPOT BACK LIGHTING

FIGURE 9

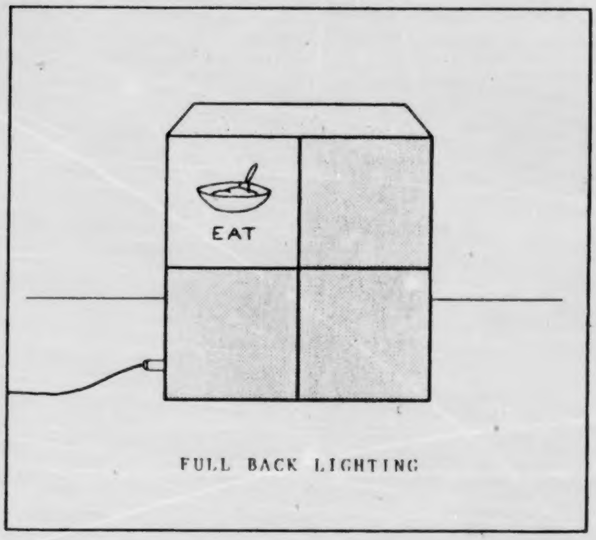

EAT
FULL BACK LIGHTING

FIGURE 10

Comparison of Indication Approaches

To test and compare the various approaches, a test setup was constructed which was capable of demonstrating each of the different methods. This setup was then used to gather information on the different approaches from teachers and clinicians.

Because this aid was to be used with very young and mentally retarded children, the corner light method of indication was not seen as being appropriate by the reviewing field clinicians. It was thought that the concept of using a juxtaposition light to indicate a picture was beyond the skill level of some of the children with which the aid would be applied. Although the edge lighting was seen as being better than the corner lighting, it was also judged to be not as appropriate as the back lighting approaches. Of the four approaches, the full back lighting approach was by far the most desired and recommended approach by the field clinicians and teachers. The spot back lighting was not as heavily endorsed, but has design and power advantages that would probably make it worthwhile to also field test a version using this technique to provide comparative evaluation with the full back lighting approach.

Bi-directional Lighting

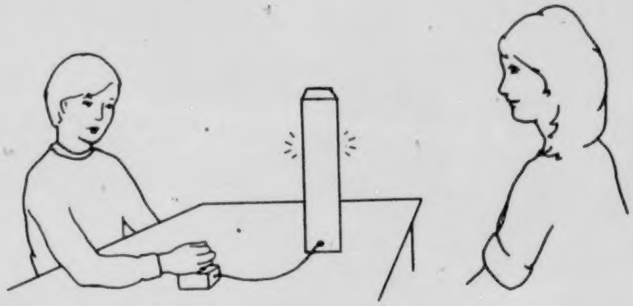
Bi-directional lighting refers to the illumination of squares on both sides of the communication aid at the same time (see Figure 11-A). This technique would allow the teacher, parent, etc. to face the child when communicating, rather than having to sit behind the child or to his side. Although this technique could be used with any of the lighting approaches mentioned, it generally means doubling the number of lights. It may be possible, however, with some of the techniques, to use the same light to illuminate both sides of the aid. This is particularly true when an incandescent light bulb is used (see Figure 11-B).

D. Scanning Pattern

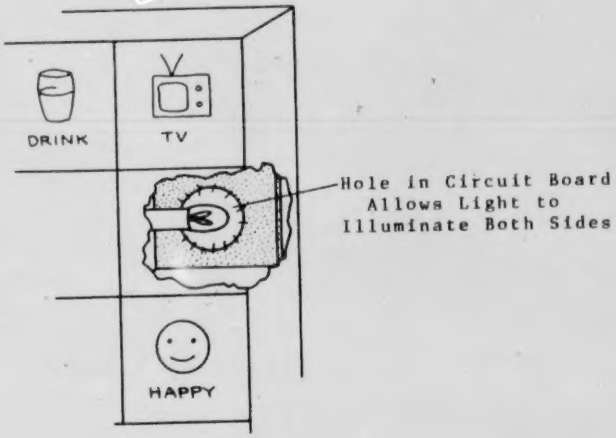
Different types of scanning patterns could also be used with such an aid. The three most common approaches would be circular, left-to-right, and row-column. Each of these approaches is illustrated in Figure 12.

With the circular scanning pattern, the lights simply illuminate the squares one at a time,moving in a circular fashion around the aid. With the left-to-right approach, the squares are illuminated in the same pattern as one uses when reading. In the row-column technique, all of the squares in a row are lit one row at a time until the child signals. The squares in that selected row are then lit up one at a time until the child signals again.

Since this aid was to be used by very young children or by mentally retarded children, it was decided that the most appropriate scanning pattern would be the circular scanning pattern. This particular pattern allows the maximum predictability and was thought to be the easiest pattern for tracking.



A. Bidirectional Aid Lights up Squares on Both Sides to Facilitate Face to Face Communication.

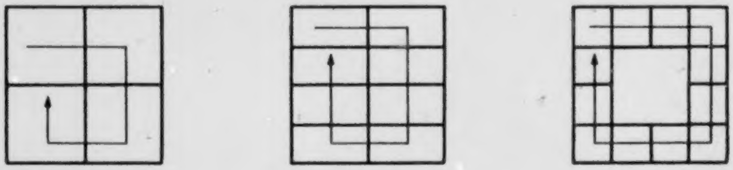

DRINK
TV
Hole in Circuit Board Allows Light to Illuminate Both Sides
HAPPY

B. A Bidirectional Aid Using a Single Incandescent Bulb.

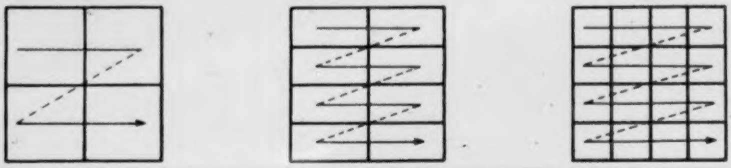
FIGURE 11

Bidirectional Lighting

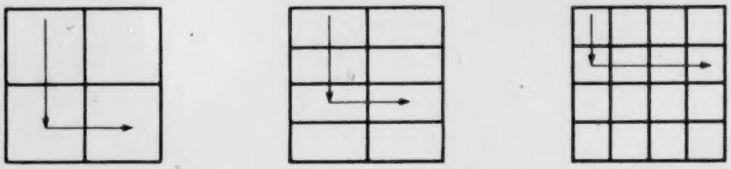
SCANNING MODES



A. Circular Scanning



B. Left to Right Scanning



C. Row/Column Scanning

FIGURE 12

Three Most Common Scanning Approaches

Within the circular scanning pattern, there were two additional choices that were considered. One was a true circular pattern shown in Figure 6, whereas the second approach was a more square-shaped pattern shown in Figure 12 . Whereas the round pattern allowed for a much smoother scanning pattern where there was no abrupt changes in direction, the square scanning pattern was thought to be a little easier to use and also allowed more versatility in terms of the variability in number of display choices.

V. PRELIMINARY DESCRIPTION OF THE ALTERNATE APPROACH SCANNING COMMUNICATION AID

As a result of the formative evaluation and field review of the various ideas presented, the following design has been reached. This design exists only on paper at this point, but a prototype based upon this design is currently under construction and field testing under separate funding from the Wisconsin Association for Retarded Citizens.

The aid, which for the time being will be referred to as the SCITA (Simple Communication Initiation and Training Aid) would use a full back-lit indication approach. The aid would be capable of scanning in either a circular pattern (counter-clockwise) or in a row/column fashion. The circular pattern would be used for young children or for introducing the aid. The row-column scanning mode would be used to train the children for more advanced aids when they are ready to move up. The circular scanning pattern would move counter-clockwise in order to facilitate transfer to the row-column method later on. A directed scanning technique which uses a joystick for its input may also be implemented to train for other aids.

The aid would be approximately one foot square x 1-1/2" deep. It would be completely battery-operated and would weigh approximately seven pounds. The case would be made out of a high impact plastic to maximize durability. The entire electronics for the aid would be on one circuit board to minimize construction costs. The squares on the aid would be approximately 1-1/2" square when used in the twelve selection mode. The bottom right-hand square would control a buzzer which could be used by the child to call for help or attention.

The illumination of the squares could be controlled by a small knob on the side of the aid. This knob would allow the illumination of the squares to be turned up so that it would be visible in sunlight, and be turned down to help conserve power in situations where the bright light was not necessary. Turning the brightness of the squares down would also help to reduce the distraction factor that might be caused by a brightly flashing light in a classroom situation. There was also some concern about brightly flashing lights in situations which may involve epileptic children even though the flashing rate is much slower than the trigger rate for epileptic individuals.

The aid would have a simple flip-down plexi-glass front sheet and to four, eight, and twelve. Similarly, the sides of the pictures can vary much more than on the back lit display. Pictures cut from magazines which have printing on the reverse side can also be used with the Rotocom, whereas they cannot be used with back lit displays since the printing would show through. Preparation of inserts for the aid is also quite simple since it only involves pasting pictures onto a piece of stiff paper. Lessons can therefore be easily and economically prepared in advance and used with the aid.

Another advantage of the rotating pointer is the simple continuous sweeping motion of the pointer. This was seen by some as being more relaxing than the jumping light. It was also seen as being perhaps more acceptable in the classroom situation whereas a blinking light may be a distraction to other children.

Disadvantages

The major disadvantages of the rotating pointer aid had to do with questions as to the ability of the very young or mentally retarded child to grasp the concept of the pointer. Also of high concern was the distractability of having a moving object such as the pointer in the child's visual field. It was thought that tracking the movement of the pointer while keeping track of his choice and trying to determine when the two were in correspondence could be a difficult task for the young or mentally retarded child, whereas there would be a similar problem with the moving light. It was the belief of some clinicians that it would be easier for the child to concentrate on what he would want and to see it lit up than it would be to look at what he wants and signal when the arrow had reached it. Which of these two approaches would, in fact, be more difficult for the child is not known, but will be examined in the comparative evaluation.

Another disadvantage that was mentioned for the rotating pointer was the motor noise of the aid. If the design included a motor with gear train, there would be the possibility of having a continuous whirring or grinding noise whenever the aid was being used Although this noise may be slight or small, care would have to be taken to keep the noise to a minimum to avoid its distraction or to avoid getting on the nerves of the individuals working around and with the child.

B. Back Lit Communication Aid

In reviewing descriptions and sketches of the back lit communication aid, the following advantages and disadvantages were cited in comparison with the Rotocom.

Advantages

The principle advantage mentioned seemed to be the very obvious way in which the scanning aid indicated the element by fully illuminating it. The clinicians and researchers thought this to be very important when used by children whose cognitive abilities were still in the early tiny self-stick pads to hold the pictures in place on the surface of the aid. Because of the variable brightness of the bulb, pictures that were printed on the regular paper could easily be used with the aid. Pictures printed on cardboard, etc. could be xeroxed first and then used.

As with most scanning communication aids, the SCITA would be able to be used with most any input switches including the switches presented in Figure 3.

The aid would not be able to scan different number of squares (e.g., 4, 8, 12, etc.) as shown in Figure 12, but would always scan the full round of 16 when scanning circular or 25 when scanning row/column. This was decided upon largely to save complexity and keep the cost low. Another advantage for using all 16 squares even when you are only working with four choices (as on a test) or four words, (when communicating) is that it greatly increases the reliability and clarity of the child's response. With only four squares, the child selects one no matter what he does, even if his motion is accidental (see Figure 13) or random. With the 16 squares, it becomes evident very quickly if he is randomly hitting the switch since he will be stopping it often on blank squares - obviously not a right or a wrong choice. If the child's timing is off and he hits early or late, his error is also more easily perceived when it lands on a blank square (as with the 16 squares system) than when it lands on another answer square (as with the four squares approach). If the child consistently stops the light one square after another with something in them, it is also easy to note that the speed may be set too fast for him. Thus a system with more stops than there are legitimate choices may provide much valuable feedback to the teacher as to the intentions of the child.

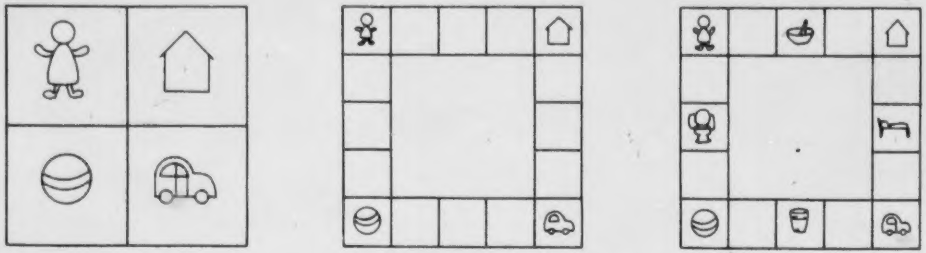
VI. COMPARISON OF APPROACHES

When confronting clinicians with both a description of the Rotocom and a description of the new aid, a variety of advantages and disadvantages for each of the aids was advanced. The following is a summary of those comments.

A. Rotating Pointer Communication Aid (Rotocom)

Advantages

The major advantages cited for the Rotocom had to do with its sheer simplicity. It was seen as being a highly reliable approach and also one that would be fairly simple to construct and maintain. The clear plastic pointer on the aid has a slot in the end to allow one to put a red ball or other large visible object, thus eliminating some of the "pointer concept" problem which may be present if using an arrow with a young child. The rotating pointer also allows the aid to be continually expanded from two to any number of choices which one would like to display on the surface of the Rotocom, whereas the light display is limited



PHYSICAL ERROR DETECTION USING DIFFERENT TYPES OF DISPLAYS

A. Four Choices on Four Selection Squares.

B. Four Choices on Sixteen Selection Squares.

C. Eight Choices on Sixteen Selection Squares.

FIGURE 13

Physical Error Detection Using Different Types of Displays to four, eight, twelve. Similarly, the sides of the pictures can vary much more than on the back lit display. Pictures cut from magazines which have printing on the reverse side can also be used with the Rotocom, whereas they cannot be used with back lit displays since the printing would show through. Preparation of inserts for the aid is also quite simple since it only involves pasting pictures onto a piece of stiff paper. Lessons can therefore be easily and economically prepared in advance and used with the aid.

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Disadvantages

The major disadvantages of the rotating pointer aid had to do with questions as to the ability of the very young or mentally retarded child to grasp the concept of the pointer. Also of high concern was the distractability of having a moving object such as the pointer in the child's visual field. It was thought that tracking the movement of the pointer while keeping track of his choice and trying to determine when the two were in correspondence could be a difficult task for the young or mentally retarded child, whereas there would be a similar problem with the moving light. It was the belief of some clinicians that it would be easier for the child to concentrate on what he would want and to see it lit up than it would be to look at what he wants and signal when the arrow had reached it. Which of these two approaches would, in fact, be more difficult for the child is not known, but will be examined in the comparative evaluation.

Another disadvantage that was mentioned for the rotating pointer was the motor noise of the aid. If the design included a motor with gear train, there would be the possibility of having a continuous whirring or grinding noise whenever the aid was being used. Although this noise may be slight or small, care would have to be taken to keep the noise to a minimum to avoid its distraction or to avoid getting on the nerves of the individuals working around and with the child.

B. Back Lit Communication Aid (SCITA)

In reviewing descriptions and sketches of the back lit communication aid, the following advantages and disadvantages were cited in comparison with the Rotocom.

Advantages

The principle advantage mentioned seemed to be the very obvious way in which the scanning aid indicated the element by fully illuminating it. The clinicians and researchers thought this to be very important when used by children whose cognitive abilities were still in the early development stages. The other advantages cited for the aid seemed to be of much less importance than the one just discussed. The reliability of the back lit aid was seen to be increased by the lack of moving parts. The fact that light bulbs could burn out, however, might offset the advantage here. The aid is also silent in its operation.

One item which is listed both as an advantage and a disadvantage is the jumping light. This is seen as a disadvantage in that it may be distracting and possibly bothersome over time. On the other hand, some teachers and clinicians thought that the light which jumped at regular time intervals would help the child to develop a rhythm which would allow him to respond more quickly by allowing him to anticipate the lighting of the desired square. If this, in fact, could allow the child to operate the aid at a slightly increased speed, it would greatly reduce his communication time and frustration. This "rhythm" effect can probably best be measured by comparing a back lit scanning system in which the lights turn on and off suddenly, causing the jumping effect, with the back lit system where the lights fade on and fade off, causing more of a floating effect. If the "rhythm effect" is significant, there should be a measurable difference in the speed with which the two systems can be run and still achieve the same selection success rate. Such a comparison has been recommended as part of the planning for the comparative evaluation of the two aids.

Disadvantages

The disadvantages mentioned most were the flashing lights and the need to use translucent display materials. The flashing light was seen to be a detriment, not so much in the child's use of the aid, but in the use of the aid around other children or in a classroom situation. In these applications, the flashing light may be a distraction problem as discussed earlier. Dimming the lights may solve much of this problem. The need to use translucent materials was seen as somewhat inhibiting, since it bars the use of magazine pages and photographs among other things. The fact that these light bulbs could be turned up so the aid could be used with regular paper decreased this problem somewhat. Turning the lights up, however, either decreases the battery life of the aid or increases the number of batteries required for the aid. The batteries would be rechargable, but their cost is significant.

VII. CONTINUING EFFORTS ON THIS PROJECT

Work is continuing on this project under the auspices of the Wisconsin Association for Retarded Children. In cooperation with Central Wisconsin Center, the Trace Center is currently continuing this design process and developing a prototype of the back lit communication aid. Upon completion of the prototype stage, a comparative evaluation program will be implemented with the back lit communication aid and the Rotocom. Further efforts concerned with the final design and dissemination of either the Rotocom or the back lit aid will be based upon the results of that comparative evaluation program.

PORTABLE MICROPROCESSOR BASED COMMUNICATION AIDS FOR NON-VOCAL SEVERELY PHYSICALLY HANDICAPPED INDIVIDUALS

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I. INTRODUCTION

The last few years have seen the development of a whole new range of communication aids for severely physically handicapped children and adults. Portable aids as well as aids which can print whole words, phrases and sentences are now becoming available to meet the needs of severely physically handicapped individuals who are not able to communicate through speech. These aids use a variety of different approaches, including scanning, encoding and direct selection (Vanderheiden-Grilley, 1976) (Raitzer et al. 1976) (Luster, Vanderheiden, 1975) in order to meet the needs of individuals having different problems and abilities.

Among these aids was the original Autocom, an auto-monitoring communication board developed at the University of Wisconsin-Madison. Like the other aids available, the Autocom went a long way toward meeting the communication needs of some severely handicapped children, but, being of the first generation of communication aids, only partially met the complete listing of needs and constraints of the non-vocal severely physically handicapped child. Among the needs and constraints which were addressed by the original Autocom were need for portability, durability, printed output (self-contained strip printer), control of page printers (typewriters) or other output forms (TV display, voice synthesizer, phone, computer, etc.), ability to print words/phrases and be used with pre-spelling and pre-reading children, the ability to use erratic pointing/sliding movements to control the aid, and adaptability of input interface. Needs and constraints which were not well addressed by the original design of the portable Autocom, however, were correctability, highly visible display for feedback, flexibility, ability to operate using different techniques (various encoding, scanning, direct selection techniques) to meet needs/abilities of different types of individuals, adaptability - ability to be altered to fine tune operation of the aid to individual abilities, ability to be used with larger vocabularies (over 200 words), teacher and user adaptability, ability to carry out other functions, and any developmental capability. Also not well addressed were the problems of low production (higher cost) and the resultant availability of widespread maintenance.

Correctability here refers to the ability of the user to "back up" and correct errors in the output message made due to physical, spelling or language development problems. Field studies have shown that this feature, along with an easily visible display of the message under construction, is extremely important to language development, especially in the early years. Children who are unable to produce good sentences on the first try are often able to correct their sentences and learn at the same time if they have a display which allows them to view and correct their message before it is printed out. A good example of this was provided accidentally by an older individual who had been using a manual communication/spelling board for many years. She was printing a message on a correctable TV display, while a non-correcting strip printer recorded the process leading to the final message. Table 1 shows the comparison. Whereas correctability was available in the form of a TV display in the earlier Autocom, the user had no highly visible or correctable display on the portable aid, and, therefore, did most of his communication away from the work station, blind to the output.

TABLE 1

Comparison of Message on Non-Correcting Strip Printer vs. Correctable Display

PLEASE THANKS TO COFOR COMEDING

(uncorrected message printed out on non-correctable strip printer)

THANKS FOR COMING

(actual corrected message, which was displayed on a correctable display)

The ability for an aid to be flexible (able to operate in different modes) is important for several reasons. First, it is rare that a single technique will best meet the needs of an individual. Usually, the best approach is a combination or hybrid of two or more techniques. If an aid is constrained to one mode of operation (scan, encode or direct selection), then its ability to match the needs of the user would be reduced. Secondly, it is difficult when working with a severely, multiply handicapped child to know in advance which technique will work best in the long run. The child's skills improve over time and the appropriate or best approach usually is not evident until the child (or adult) has been working with different approaches for awhile. It is therefore difficult to pre-guess which type of aid to buy and expensive to purchase several in order to work with them all. It is also quite common that an individual may grow from one technique to more efficient ones over time,requiring him to purchase new aids repeatedly to take advantage of his development if his original aid is not flexible enough to be re-programmed to operate in these new modes itself.

Adaptability here refers to the ability of the aid to be tailored to the specific needs and abilities of an individual. Different input switches or handpieces have provided some adaptability to present communication aids. Teachers/clinicians, however, have complained that present aids are much more limiting than manual techniques (such as a regular pointing communication board) and restrictive. Some specific areas mentioned with regard to the Autocom were fixed alphabet arrangement and location, limited wordset, fixed wordset or wordset which could not be easily changed or added to from week to week by the teacher or the student himself, speed control not adjustable by the user and pointing area, square size and square location on boards surface not user specifiable. In addition, adjustments to the operational mode (adaptations to a specific scanning or encoding technique, for example) to make the aid more easily used by an individual would also come under the category of adaptability.

Of primary concern to many parents as well as teachers/clinicians was the relative inability of the original Autocom and other aids to be able to take on a very simple form for use with very young pre-spelling, pre-reading children who may have little language skills and yet meet the more complex communication needs of these individuals as they grow and develop. Outgrowing communication aids is very expensive and securing a second aid is even more difficult than securing the first. Thus, it is desirable to secure one which can be grown into but which does not hamper development by being overly complex to start with. This problem of needing but rapidly outgrowing a simpler aid is more prevalent with older but severely delayed children with mild or moderate mental retardation (MR) but also occurs with very young children. It should be remembered that a normal five year old child has a vocabulary of about 2500 words and very diverse communication and interaction skills and needs.

Finally, the two major problems faced by all the aids in this field are high cost of aids and limited availability of maintenance. Both of these problems are chiefly caused by the low volume production that is characteristic of these aids. These problems are compounded, however, by the lack of flexibility of aids which leads to a need for more types of different aids. Thus, a small market is broken up into smaller ones and the maintenance problem increases with each additional non-standard aid. The other major factor leading to high cost of the aid is the need for fitting or adapting the aid to best meet the needs and abilities of the user. This is especially important when working with severely multiply handicapped individuals as most of these children or adults are. One trip to fit or follow up on a child may cost 25% of the cost of an aid. Again, this problem is compounded by the limited teacher adaptability of the aids and the diversity and non-standardness (lack of similarity) of the various aids. Local clinicians and even rehabilitation engineers would find it difficult or impractical to become familiar with the many different aids, their features, adaptations, etc., in order to be able to select, fit and adapt the various aids without substantive assistance from the developer/manufacturer.

Because of needs such as these expressed by teachers/clinicians in the field, Trace Center established a program to explore the development of a control module which could serve as the core for a whole range of very flexible/adaptable communication aids.

It was hoped that this "universal control module" could be designed such that it:

- would be able to serve as the control section for most any type of communication aid: scanning, encoding, direct selection or combination

- would be part of a universal control system which would comprise the bulk of the needed electronics for an aid and could remain the same in a range of different aids

- would be very flexible and allow for maximum adaptability by the manufacturer, teacher/clinician and the user himself

- would allow the development of "developmental" aids which could grow and expand function with an individual as he/she grew

- would allow for easy access and changing of a large vocabulary of words, phrases, and sentences

- would lower the cost of an aid below what it would cost if it were designed using discrete logic (by reducing number and complexity of subassemblies)

-would lower costs due to larger production of major portion of aids due to use of common system

-would allow for lower maintenance cost and wider availability through self-diagnostic capabilities and common subassemblies and electronics across aids

-would provide other researchers as well as research clinicians/teachers with a flexible core mechanism around which they could implement their new ideas and develop new types of aids for specific users without having to develop all the support materials, documentation and production/maintenance mechanisms

-would allow for the use of a common set of accessories and materials across a wide range of fully compatible aids

Funding for the first two phases of the program has been provided by the Bureau for the Education of the Handicapped, Office of Education (HEW) as a part of grants OEG-0-74-7461 and G007601628. During Phase I, a prototype of the module was developed along with a prototype of scanning and an encoding aid which use the module. During Phase II which is still underway, the prototypes will be further developed, evaluated through field placement and review by other researchers and modified per the evaluation results. Under separate funding, the Autocom was redesigned using the universal control module and the packaging format for the encoding aid. Forty of the new versions, now called the Autocom-E, are currently being placed across the United States and Canada on a cost basis as part of an open field test/tracking program. A Bliss Symbol printing aid has also been developed using the universal control module under funding from the Blissymbolics Communication Foundation and the National Research Council of Canada. This paper will describe the universal control module and the aids developed through these programs.

II. DESIGN PROCEDURES

A. UNIVERSAL CONTROL MODULE (UCM) DESIGN

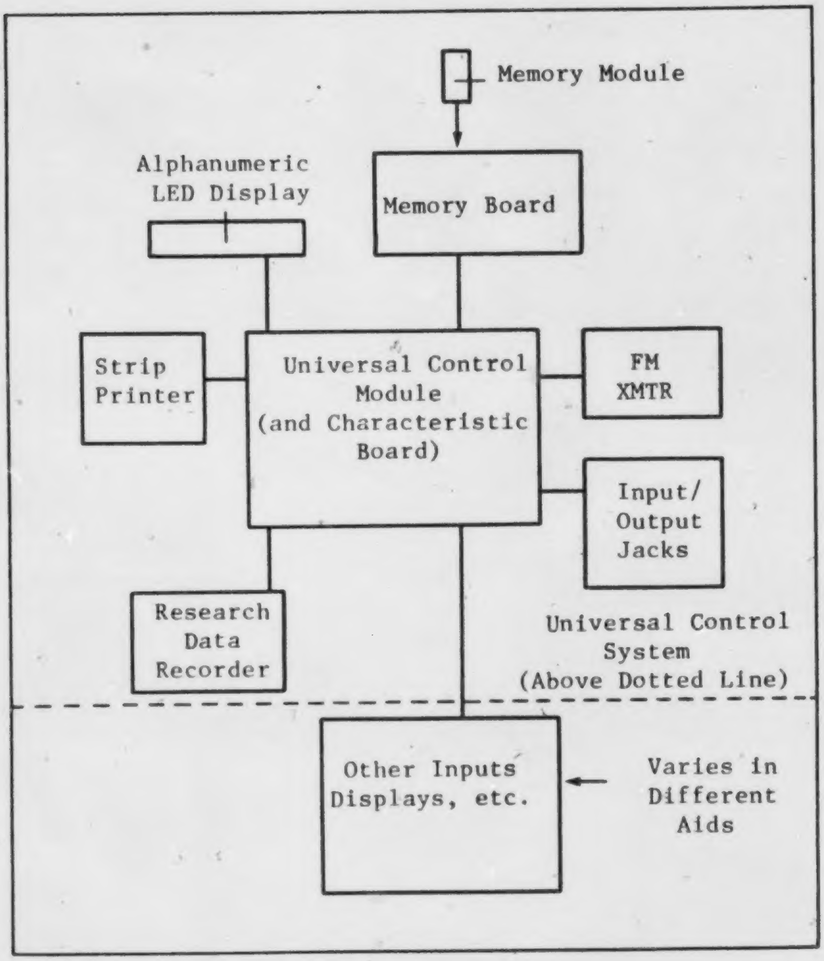
Because the universal control system and the modules connected to it will comprise about ninety percent of the electronics of any communication aid designed around it, most of the features and capabilities of an aid would be defined by the control system. For this reason, a major portion of the design considerations were centered around the design of the universal control system. The principle design consideration for this system centered around the areas of power consumption, size, cost, versatility, adaptability, reliability and maintenance.

The power consumption and size of the module were principle concerns because of the need for the aid to be portable and battery operable. In addition, it was necessary to design a module which would have an extremely low power consumption when left turned on, but in a stand-by mode. This was necessary, since it was desired that the eventual communication aid would be operative at all times so that the individual would never be cut off because his aid was turned off when he couldn't turn it on. For these reasons, a low power COS/MOS microprocessor made by RCA (the Cosmac) was chosen as the core for the system and C-MOS digital logic was used throughout the rest of the system design. The only exceptions were the programmable read-only memories which are only turned on for the brief instant in which they are being used. By using a simple microprocessor based system, the cost of the total electronics was reduced to about two-thirds of the cost of a similar but less flexible design which used regular discrete digital logic.

To provide for maximum adaptability (the ability of the UCM to be used in the design of different types of aids) the universal control module was designed to operate with an octopus-like structure (Figure 1). With this structure, the universal control module would form the hub and directly control each of the peripheral accessories or features of the communication aid. In this manner, features, output modes, or input modes could be added or deleted easily without changing the basic structure of the system. Figure 2, A, B, and C show how the universal control system could be used with various input formats to develop very different types of communication aids. Figure 3 shows how the universal control system can also be easily adapted to perform widely varying functions. In all of these applications, no physical modification of the module itself is needed. The only change would be in the program which is fed to the module.

Because of the importance of having the aid always available for the handicapped individual, the reliability and ease of maintenance were a prime concern in developing the system. The design team attempted to maximize the reliability of the system through: 1) minimization of electronic parts, 2) elimination of mechanical parts wherever possible, 3) localization of failure techniques which ensured that failure in one section could not cause damage in other areas, 4) the implementation of an auto-reset system. Ease and speed of maintenance were maximized primarily through the modular construction by containing all the major electronics on two easily replaceable printed circuit boards. In addition, the octopus design (Figure 1) makes localization of the problem fairly simple. If any part of the aid is operating, then the central processor system is all right. Locating the difficulty beyond that is simply a matter of checking the circuits running out the particular arm(s) which are not functioning. Under subsequent funding, manuals will be developed which will allow most any experienced electronics technician to easily identify the module at fault. Replacement can be ordered easily by phone or mail. In this manner, the time delay and cost for repair can be minimized, except in the case of severe or catastrophic damage to the aid which would require shipping the unit to the manufacturer.

Perhaps of greatest importance to the teacher in the classroom were the considerations made in the design to ensure the versatility of the



Memory Module
Alphanumeric LED Display
Memory Board
Strip Printer
Universal Control Module (and Characteristic Board)
FM XMTR
Input/ Output Jacks
Research Data Recorder
Universal Control System (Above Dotted Line)
Other Inputs Displays, etc.
Varies in Different Aids

FIGURE 1

UNIVERSAL CONTROL MODULE

(OCTOPUS-LIKE STRUCTURE)

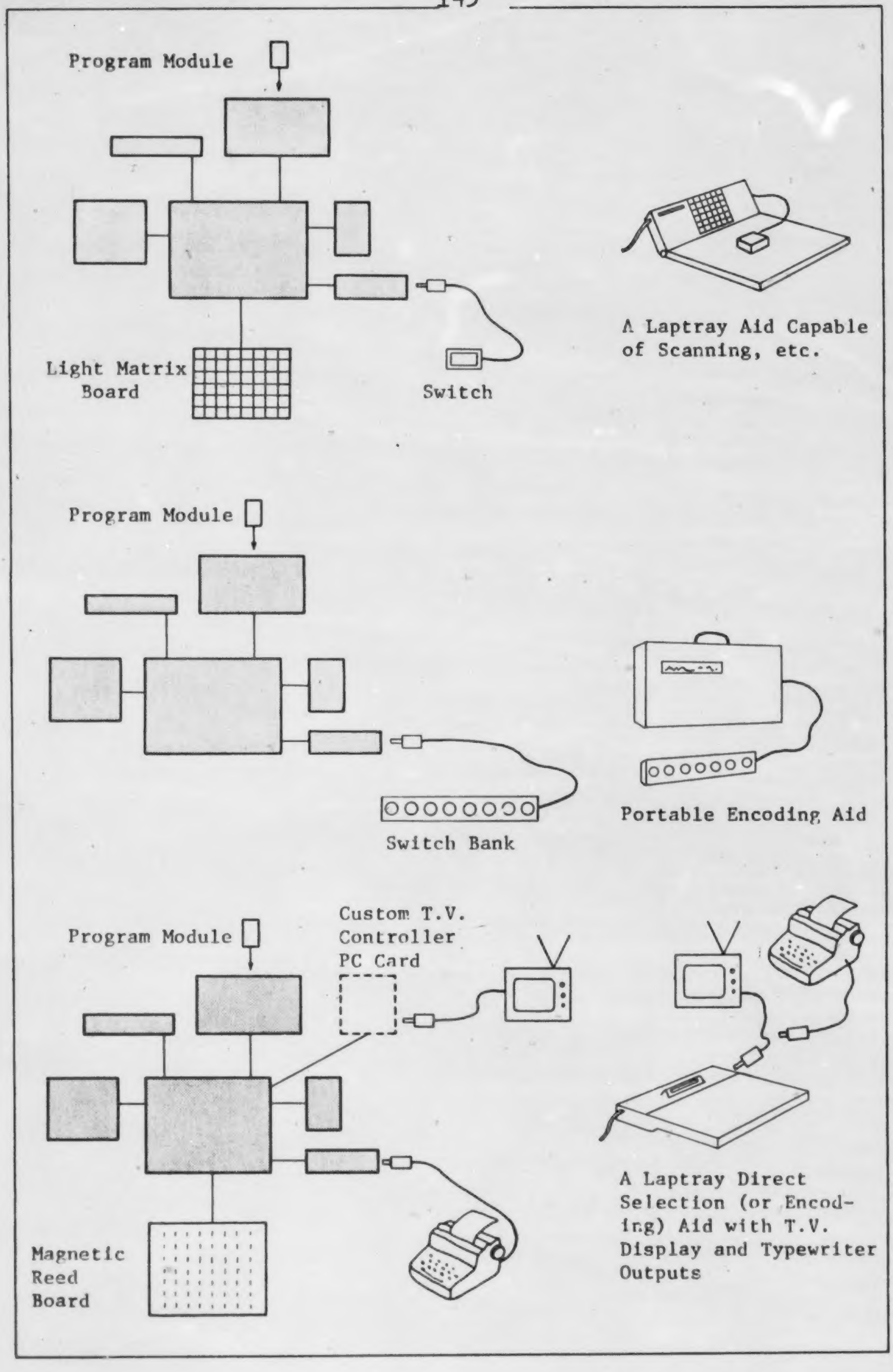

Program Module
Light Matrix Board
Switch
A Laptray Aid Capable of Scanning, etc.
Program Module
Switch Bank
Portable Encoding Aid
Program Module
Custom T.V. Controller PC Card
Magnetic Reed Board
A Laptray Direct Selection (or Encoding) Aid with T.V. Display and Typewriter Outputs

FIGURE 2

UCM AND VARIOUS INPUT FORMATS

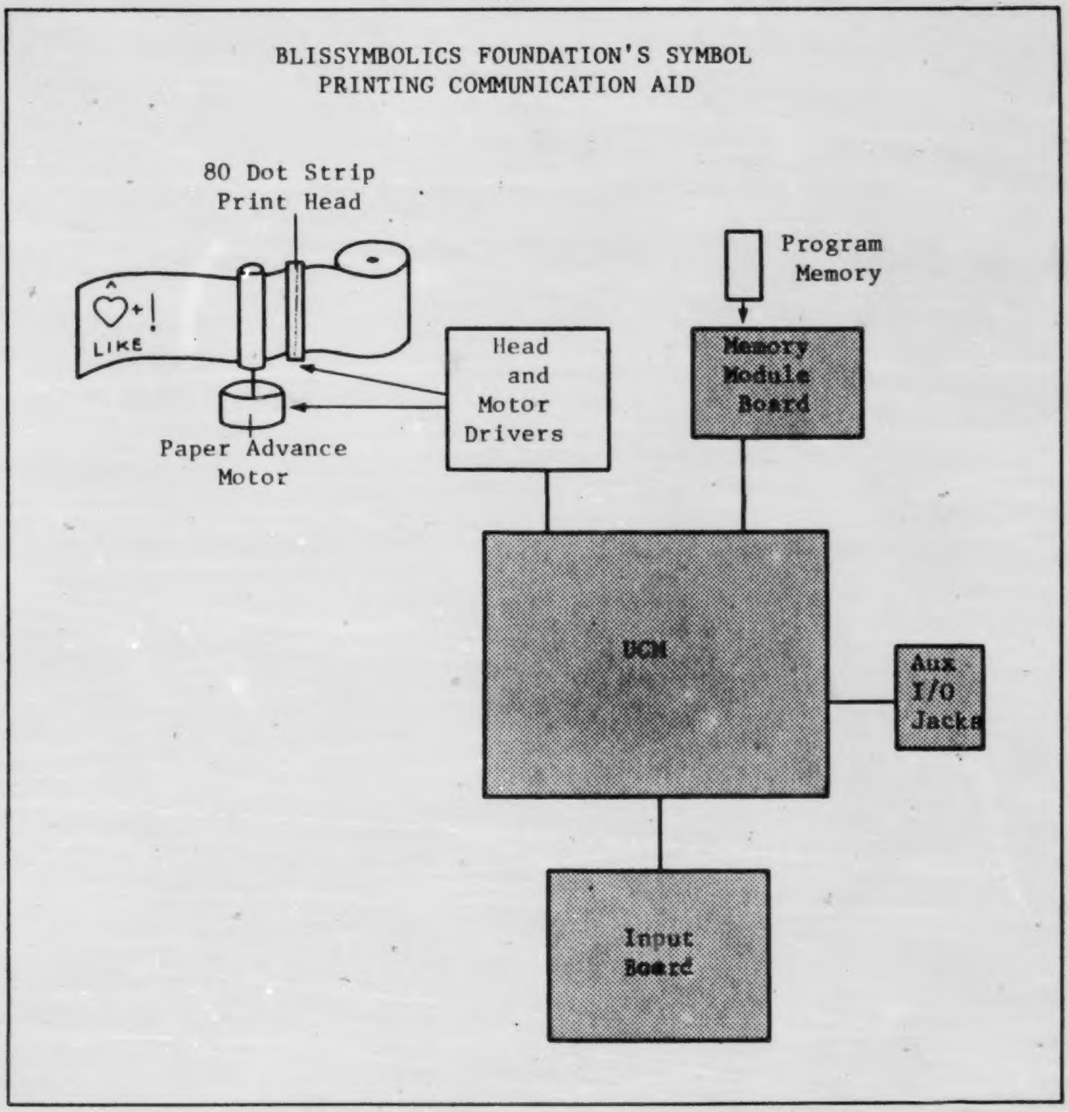

BLISSYMBOLICS FOUNDATION'S SYMBOL PRINTING COMMUNICATION AID
80 Dot Strip Print Head
LIKE
Program Memory
Head and Motor Drivers
Memory Module Board
Paper Advance Motor
UCM
Aux I/O Jacks
Input Board

Figure 3. Use of the UCM System to Create New Aids to Meet Other Needs

communication aid. The versatility is defined as the ability of the aid to be adapted by teacher/parent/clinician to specify the particular words, sentences or arrangement of the letters and words on the aid; the ability of the teacher/parent/clinician to specify the number and type of switches to be used; and their ability to specify the particular mode of operation (different types of scanning, encoding or direct selection) which would be best for their particular individual are all examples of aid versatility. The ability to re-specify or change all of these variables and others to accommodate the growth and development of the child is also a very important aspect of versatility.

To provide a mechanism for this type of versatility, an externally accessible memory plug-in board was included in the design of the system. This board has sockets into which matchbox-sized memory modules can be plugged. In designing a communication aid, this card would be placed directly in front of a sliding door which allows the teacher to have access to the pop-in memory modules (Figure 4). In this manner, the teacher would be able to change memory modules as necessary to change the operation of the aid to meet the current needs of the handicapped child.

B. RESULTS OF UCM DESIGN

The result of the universal control system project was the development of a universal control system which could function as the heart of a large number of different types of communication aids. The features and capabilities of these different aids would essentially all be identical with the only difference being their package and their input form (i.e., different scanning, encoding or direct selection input/control techniques). Some of the features of the universal control module developed, which would also be features of an aid incorporating the module, are:

1) Portability - The unit has its own self-contained rechargeable battery pack. The entire universal control module with the accessories shown in Figure 5 weighs approximately 3 pounds (batteries = + 3 more pounds) and would fit in a box approximately 5 x 15 x 150 centimeters, (2 x 6 x 20 inches, including batteries)

2) Highly Visible Display - The characters on the LED display have an effective image height of .16" and with normal vision, can be read up to a distance of 3 meters (10 ft.). The character format is that of a standard 16 segment display (Figure 6), which unfortunately is not the most desirable format for use with young children. Part of the field test procedure will determine whether or not this irregular letter format is a problem for very young children. (Other displays could be substituted as they become available.)

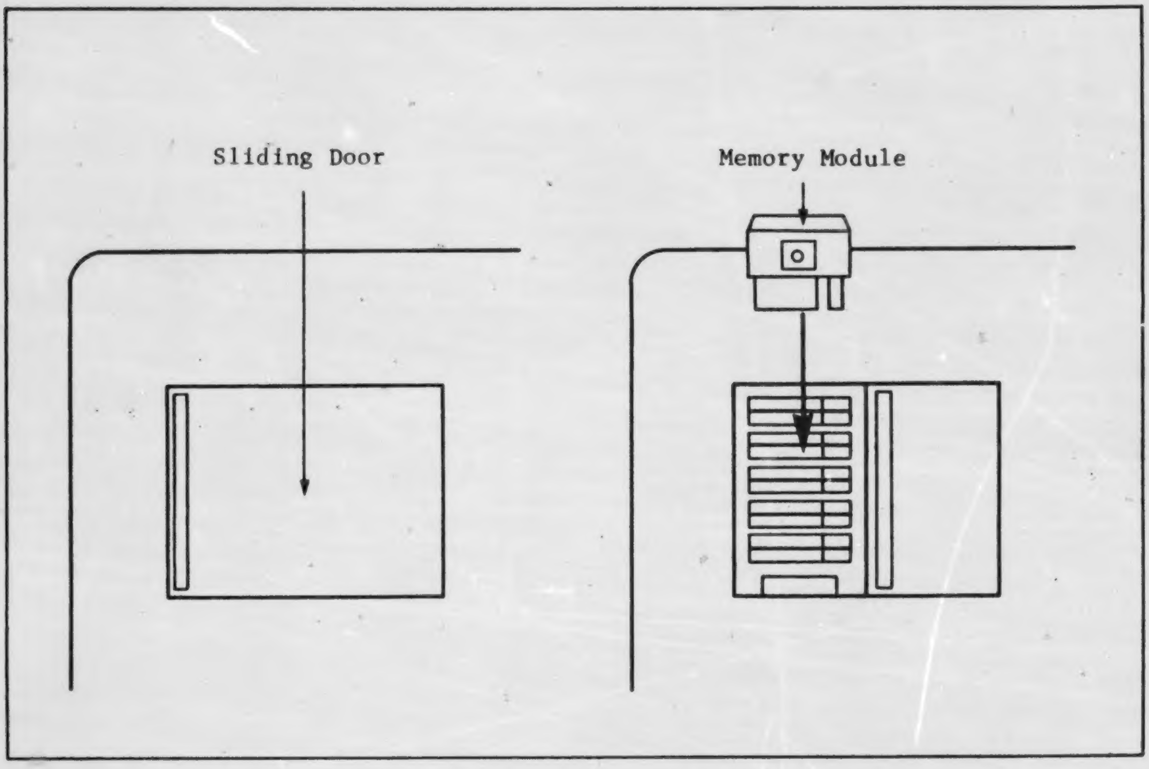

Sliding Door
Memory Module

FIGURE 4

Externally Accessible Memory Plug-in Board

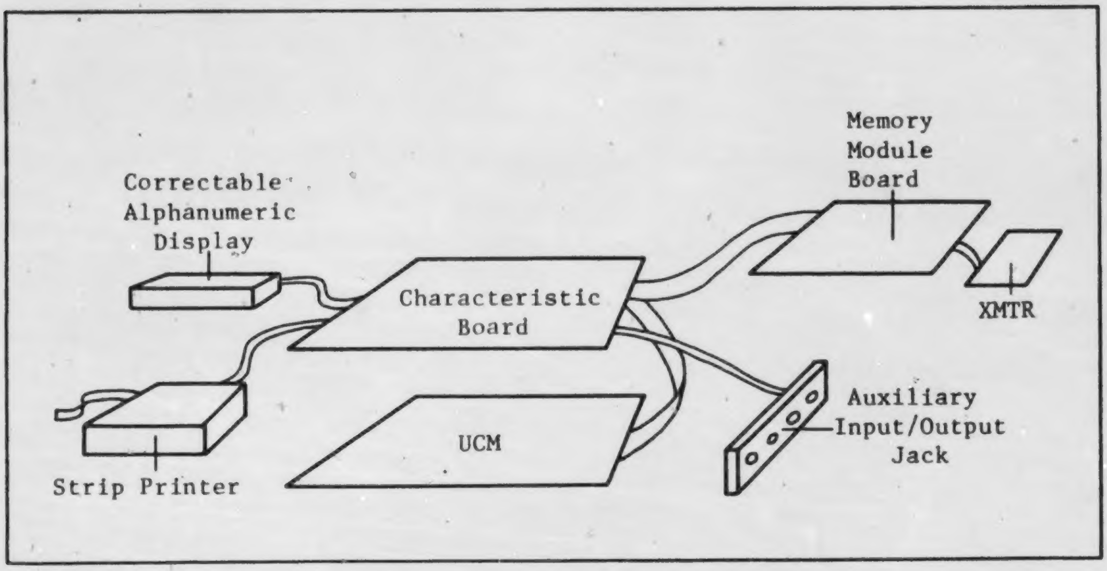
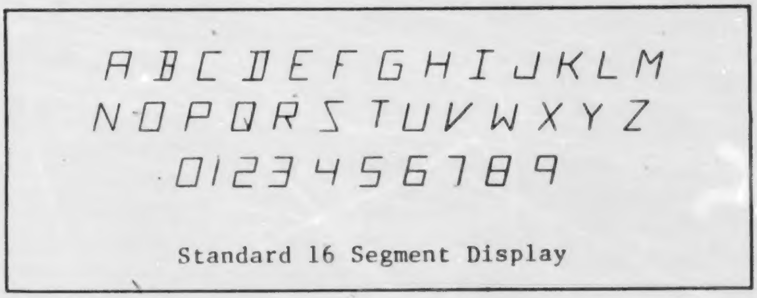

Memory
Module
Board
Correctable
Alphanumeric
Display
Characteristic
Board
XMTR
Auxiliary
Input/Output
Jack
UCM
Strip Printer

FIGURE 5

UCM and Accessories


A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
0 1 2 3 4 5 6 7 8 9

Standard 16 Segment Display

FIGURF 6

3) Correctable Display with Printed Copy - Because of special programming, the LED display, which does not normally allow for correction, is able to do both back space and back-word functions to enable the individual to correct any errors in spelling or sentence construction as he sees them displayed. As the letters are printed on the display, they move from the right to the left. As they run off the left end, they are printed out on the strip printer so that even very long messages can be constructed and preserved using the strip printer without losing the ability to make corrections. In an alternate mode of operation, the letters are entered from left to right in a typewriter fashion and only shift left when the display is full. By printing out the display each time it gets full, the shifting mode can be completely avoided if this poses a problem for some children.

4) The Ability to Print out Words, Phrases or Sentences - In addition to printing out single letters, the universal control module has the ability to print out entire words, phrases or sentences with a single signal from the handicapped user. Commonly used words, phrases and sentences can, therefore, be programmed into the unit to provide more rapid and timely communication for the handicapped individual. This feature can also be used to store and output a series of commands to the aid or to other devices. The universal control module has the ability to hold up to approximately 2,000 words.

5) The Ability to be Used With Pre-reading and Pre-spelling Children - Because of the ability to print out words and phrases, etc., the aid can be used with pre-spelling children having a sight word vocabulary. By using pictures or symbols in conjunction with the word on the child's display, the non-reading child would also be able to construct messages which could be subsequently read back to the child, providing him with oral feedback as well as a motivating mechanism for providing associations between the picture and the corresponding word(s). Connected to a voice synthesizer, such as the Votrax, the aid could both say and spell out the words on a display as the child pointed to the word/picture/symbol.

6) Versatility Needed to Adapt the Aid to the Specific Needs of the Child - The universal control module itself is capable of operation in almost any type of scanning, encoding or direct selection mode. Aids which incorporate the module would be extremely flexible due to the programability of the module and would allow for extensive modification of the particular operational mode chosen even after the aid is placed in the field.

7) Ability to Function as a Developmental Aid - Because the aid can be easily modified even after placement, the aid can be made to develop slowly with the child. The aid can be easily programmed to operate very simply when placed with a young child. Then as the child develops, the aid can be modified by the parent or teacher by simply changing the plug-in modules to meet the advancing communication and control needs of the child as he grows and to take advantage of developing physical and conceptual abilities in the child.

8) Ability to Have the Child Himself Change Words/ Phrases in the Wordmaster - Up to about 80 words can be added or changed from day to day by the handicapped user (or teacher) to meet the changing communication needs of the handicapped individual. Frequently used words, seasonal greetings, favorite quips, emotional expressions and prepared remarks are some uses for this feature. It can also be used to easily alter his permanent word store and to store series of commands for the aid or for control of devices in his environment or employment situation.

9) The Ability to Easily Interface With A Wide Range of Accessories - Since the output of the aids would be completely under software control, any length serial output string using any code can be programmed. Some examples would be ASCII, used by most computers, Baudot used by the deaf teletypers, EBSIDIC used by IBM, and special codes such as that used by VOTRAX.

10) The Ability to be Programmed by Researchers or Applications Engineers to Incorporate Their Own Special Features/Capabilities - The COSMAC is a very easy microprocessor to learn and use. Because of the design of the UCM software, programs

could be written by other researchers to expand the function of the aids or to develop new aids using the UCM system.

11) Ability for Limited Self-Diagnosis and Ease of Maintenance - Because it is a smart aid, special diagnostic programs can be prepared to aid the technician in locating problems in the aid. Because it is a static processor, the aid can be stepped through its programs, further simplifying maintenance. Since a large number of different types of aids could all use the same basic system, populations of users could be denser, allowing for the setup of local or regional maintenance centers.

12) Ability to Provide Special Functions for Education, Recreation, Independent Living, Creativity and Employment - Special functions such as calculators, sequence programmers, games, and device control could be easily added to the aid by simply plugging in special program modules. A special accessory could also be developed which would allow handicapped individuals to write their own programs for their aids.

13) A Lower Cost Than Comparable Non-microprocessor Based Aids - The cost of the aid would be less than a non-flexible aid having only the capabilities numbered 1, 2 and 4. Aids which have only a single mode of operation and spelling (no significant word output) could however be more inexpensively designed with a microcontrolled, or discreet logic and would not benefit from the UCM approach.

III. THE VERSICOM AND AUTOCOM-E

A. OVERVIEW OF THE MODES OF OPERATION

Subsequent to the development of the UCM and the UCM system, two communication aids were developed around the system. The objective in the development of the aids was to minimize the number of different package forms needed to provide a wide range of different communication aids. Since the various techniques explored could be generally broken down into two categories (those that require active selection displays such as the scanning technique, and those that do not) the least common denominator arrived at was two. As a result, two package forms were developed, dubbed the Versicom and the Autocom-E. Figure 7 shows some of the modes of operation for which the aids can be programmed as well as the accessories needed to implement them. Figures 8 through 11 describe the modes in more detail and provide some information

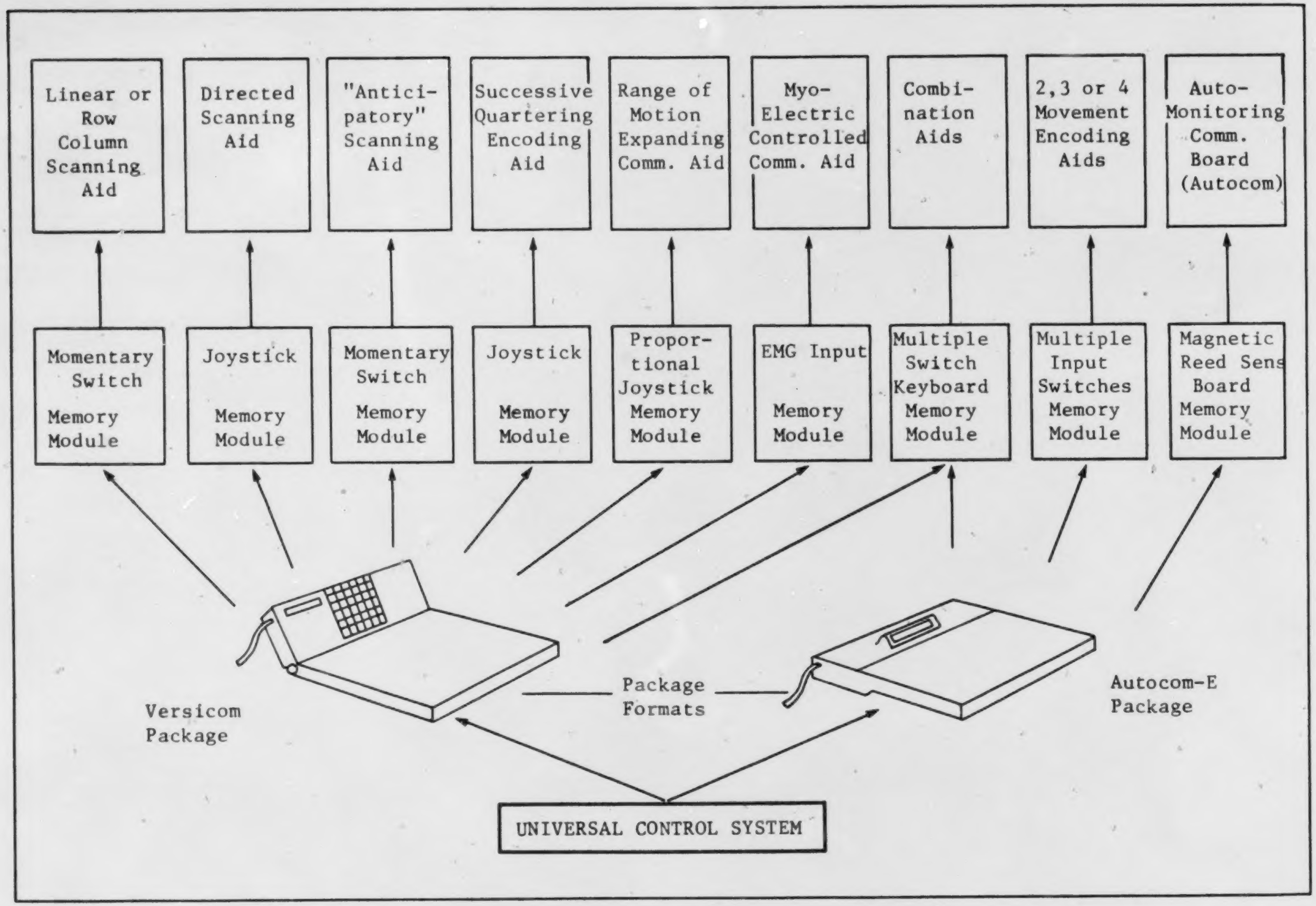
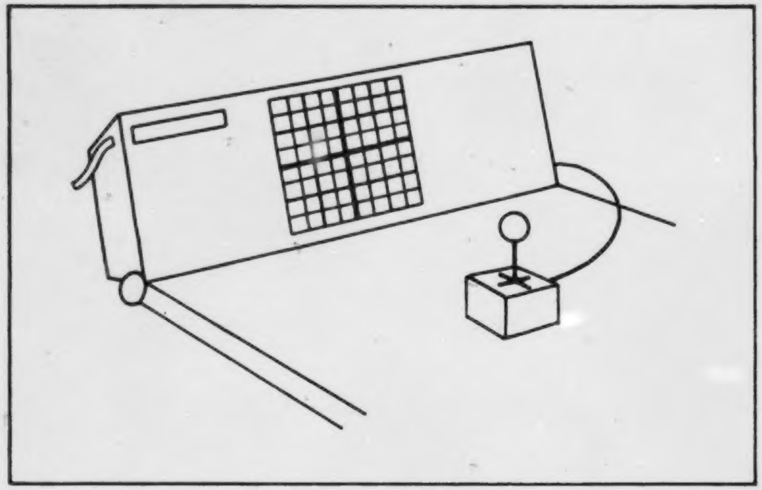

Linear or Row Column Scanning Aid
Directed Scanning Aid
"Anticipatory" Scanning Aid
Successive Quartering Encoding Aid
Range of Motion Expanding Comm. Aid
Myo-Electric Controlled Comm. Aid
Combination Aids
2,3 or 4 Movement Encoding Aids
Auto-Monitoring Comm. Board (Autocom)
Momentary Switch Memory Module
Joystick Memory Module
Momentary Switch Memory Module
Joystick Memory Module
Proportional Joystick Memory Module
EMG Input Memory Module
Multiple Switch Keyboard Memory Module
Multiple Input Switches Memory Module
Magnetic Reed Sens Board Memory Module
Versicom Package
Package Formats
Autocom-E Package
UNIVERSAL CONTROL SYSTEM

FIGURE 7

Autocom/Versicom Packages

SUCCESSIVE QUARTERING ENCODING AID



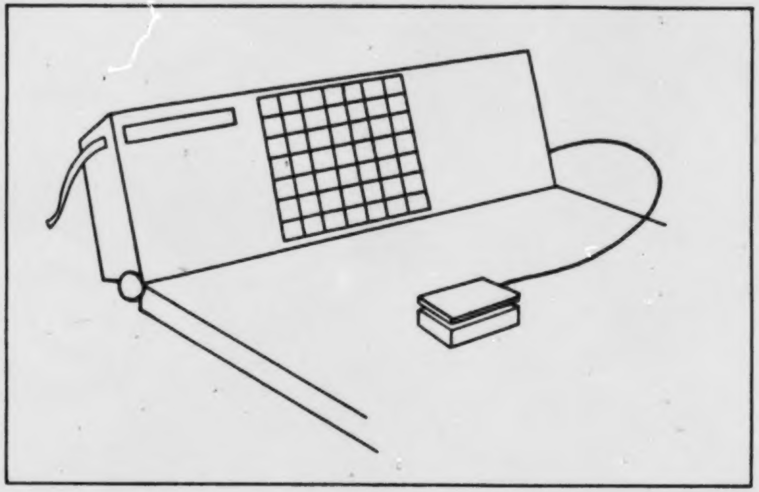
Features:

- provides visual feedback eliminating need to memorize code
- not time dependent as with scanning techniques - child moves at own speed
- three movements needed to select any square
- four switches can be substituted for Joystick if desired

Population:

- could be used with both cerebral palsied individuals and individuals having fast motor control. CP individuals would need moderate control of some extremity. Good system for individual using his foot - small transducer with good visual feedback

"ANTICIPATORY" SCANNING AID



Features:

- based upon anticipatory scanning technique developed at Tufts New England Medical School
- reduces scanning time by   % for "Row-Column" scanning aids by anticipating the next letter needed (based upon the last letters printed) and presenting the most probable "next letters" first before scanning the whole alphabet

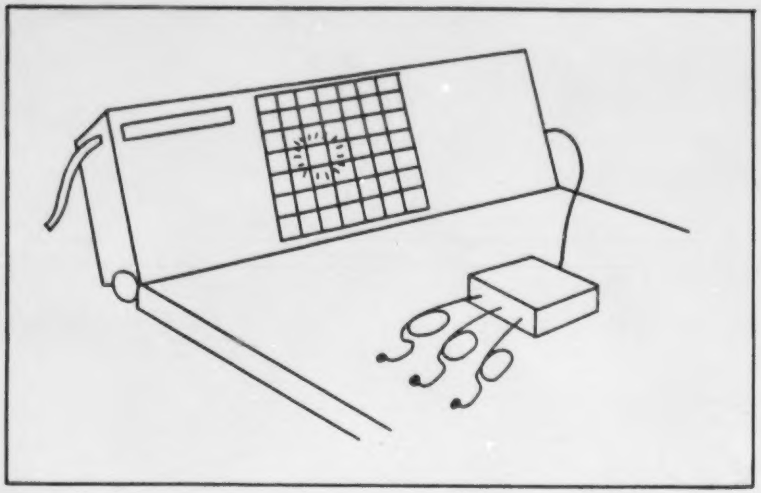
Population:

- same population as for "Row-Column" except that users should be more advanced to cope with anticipatory scanning pattern which is less straight forward

FIGURE 8

Successive Quartering Encoding Aid and "Anticipatory" Scanning Aid

O-ELECTRIC CONTROLLED COMMUNICATION AID
(Direct Selection)



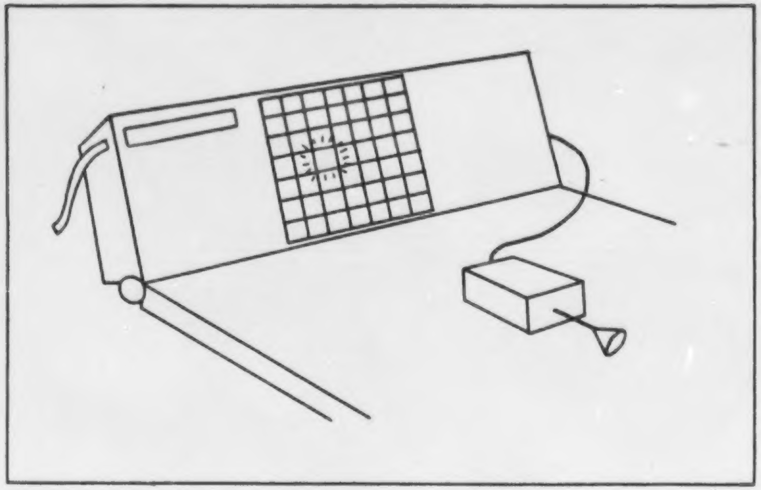
Features:

- direct control over position of lighted square through graded myo-electric input
- clear visual biofeedback inherent in system
- very fast for those who have fine control of two motor groups
- can be used as a writing aid or computer input for those able to speak but not write, etc.

Population:

- principally for individuals with spinal cord lesions or other impairments leaving them with fine motor control of at least two motor units. These can be little used neck, shoulder or arm muscles.

ROM EXPANDING AID
(Direct Selection)



Features:

- direct control over position of lighted square through proportional position controlling Joystick
- requires no electrode placement
- provides very fast control for those having fine position control in two dimensions with some part of their body (finger, chin, mouth, etc.)
- only very small ROM (range of motion) required

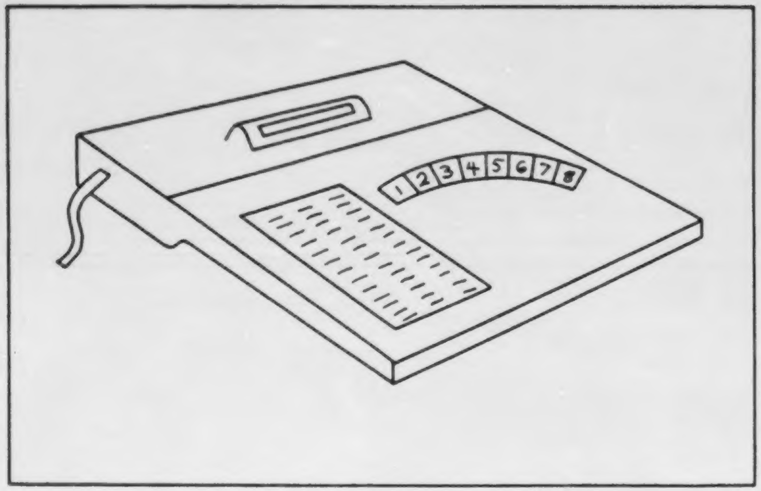
Population:

- trauma victims and others whose disability leaves them with good control but little range of motion

FIGURE 9

Myoelectric Controlled Communication Aid and ROM Expanding Aid

2, 3, or 4 MOVEMENT ENCODING AID



Features:

- requires only minimal pointing skills and limited range of motion

- any type of switches - any number of switches and switch operations can be used

- color number coding can be used for younger children

- code can be selected/developed by user

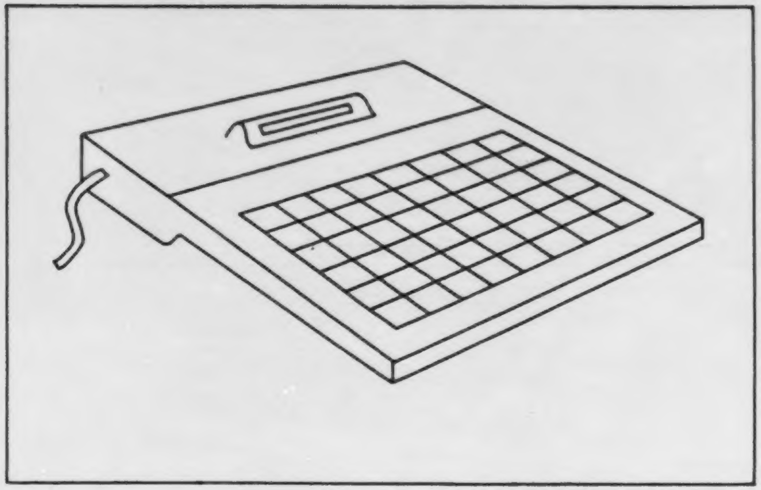
- faster than scanning but requires more control

- easy access to very large vocabularies

Population:

- for CP and other individuals who have some pointing or multiple switch operating skills but not sufficient range of motion to use auto-monitoring board. Faster than scanning especially for very large vocabularies.

AUTO-MONITORING COMMUNICATION BOARD AIDS
(Direct Selection)



Features:

- simple direct indication of desired message elements

- requires larger range of motion and medium gross control but does not require fine motor or pointing skills

- auto-monitoring technique can interpret even erratic pointing motions of many athetoid individuals

- fastest technique for those with good ROM but poor control

- slower than ROM expanding aid for those with good control

- allows for direct display of large vocabulary 128 (512) with four levels displayed

- can be combined easily with encoding technique for larger vocabularies

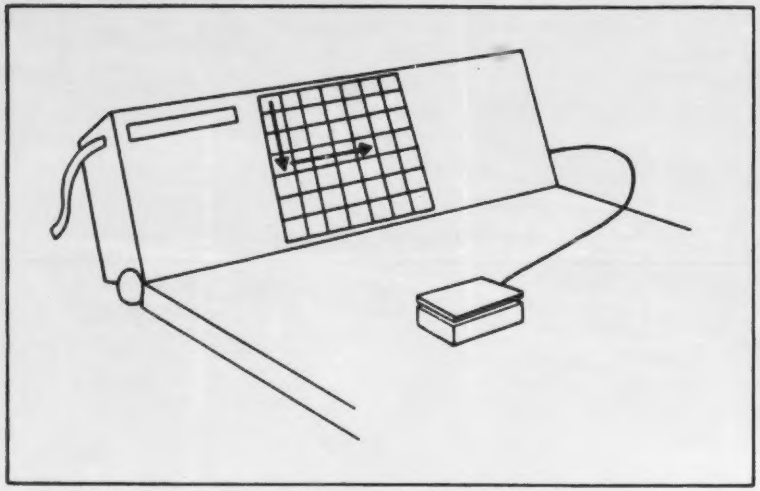
Population:

· CP, Parkisonian, other disabilities which leave good ROM and gross motor control but lack fine motor control. Good for use with young children due to simplicity and straightforwardness of direct pointing

FIGURE 10

2,3, or 4 Movement Encoding Aid and Auto-Monitoring Communication Board Aids

LINEAR OR ROW/COLUMN SCANNING AID



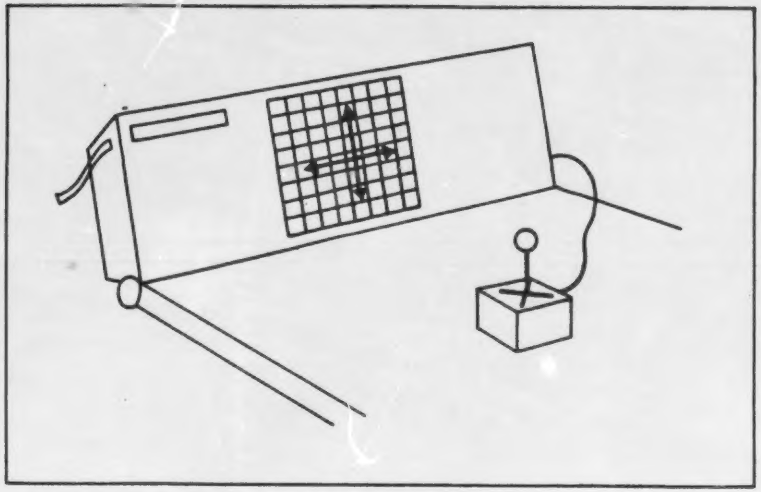
Features:

- only requires simple switch closure for operation
- any momentary switch can be used with aid
- could be used by even the most severely physically handicapped - most any movement can be tapped as the control signal

Population:

- this aid would be most appropriate for the most severely physically handicapped who have no fine or even medium control over any extremity. This aid (approach) is slower than many others but is very powerful because it requires so little physically on the part of the user. It is also fairly simple for young children.

DIRECTED SCANNING AID



Features:

- input from any four switches
- primarily used with a Joystick
- faster than "Row-Column" scan
- could be run through same Joystick that controls wheelchair

Population:

- appropriate for any individual who can use four switches or a Joystick. Allows more control and faster selection than "Row-Column" scanning but requires more physical skill. Requires less precise response timing than "Row-Column". Still simple enough for young children.

FIGURE 11

Linear or Row/Column Scanning Aid and Direct Selection Aid regarding the advantages/disadvantages of the various modes of operation. (Only modes 1, 8, and 9 have been implemented to date.) A discussion of the rationale for the final design for the two aids prototype package forms follows.

B. DESIGN CONSIDERATIONS FOR THE ENCODING/AUTOCOM PACKAGE

The overall format for the non-display aid was the simpler of the two packages to design. Since the aid had no display and only required a jack for input switches, a straight laptray design was chosen. This format allowed for clear, easy viewing of the LED output display, and a flat laptray surface on which encoding switches could be placed. In addition, it also provided a large flat laptray surface which could be covered with a sheet of plexiglass and used to display encoding vocabulary chart(s). This type of package had previously been used in the design of the original Autocom and had received good field review by the field test centers. By using this package form, both direct selection aids such as the Autocom and Encoding aids could be accommodated with a single package form. Because of the similarity to the previous Auto-Com package, the new package was termed the Autocom-E package format.

C. DESIGN CONSIDERATIONS IN THE DEVELOPMENT OF THE VERSICOM PACKAGE FORMAT

The development of the "active selection display" aid centered around two major areas: the lighting techniques for the selection display and the overall package design/shape. Throughout the design, particular attention was paid toward maintaining as much of the versatility of the UCM as possible. Since the prototype when completed was able to be programmed to operate with techniques from all three basic approaches (scanning, encoding and direct selection) it was dubbed the Versicom.

Versicom Display Design

Of primary concern in the design of the Versicom was the development of a selection display which was flexible, low power and able to be used with young children as well as adults. LED backlighting, edge lighting, spot backlighting and full backlighting were all considered and evaluated both by the research staff at the Center and by clinicians in the field.

1. Corner Light Indication

With this approach, a small indication lamp is placed in the corner of the display squares (see Figure 12). A square is then selected whenever the corner light is lit. This approach has a couple of practical advantages. First of all, it allows opaque pictures to be easily used with the aid. Any picture, card, etc., which does not cover the corner of the square can be used with this approach. In contrast, the backlighting approaches require that the pictures be transparent or translucent. The other advantage of this approach is that very low power solid state lamps (LED's) can be used as the cornerlight. These LED's

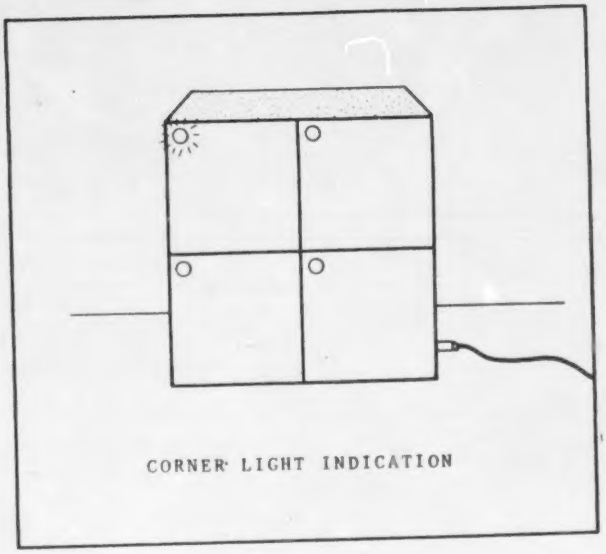

CORNER LIGHT INDICATION

FIGURE 12

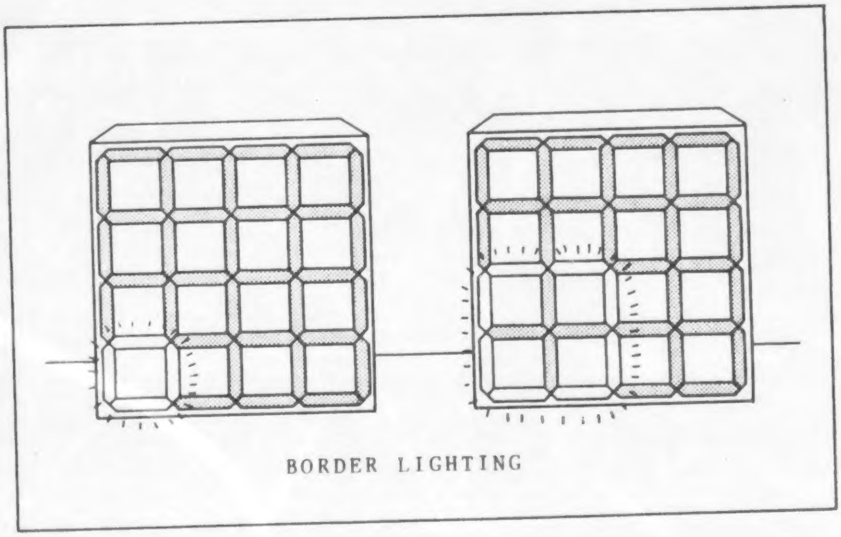

BORDER LIGHTING

FIGURE 13

essentially never burn out and also lend themselves well to battery-powered aids.

2. Edge Lit Displays

With this approach, the entire border is lit up around the desired square (Figure 13). This approach also has the advantage of allowing opaque cards and pictures to be easily used with the aid. It also has the potential for being implemented using light emitting diodes. It is slightly more complicated to construct but was thought to have some advantages over the corner light approach in terms of clearly indicating the chosen square.

3. Spot Back Lighting

With the spot back lighting approach, a small lamp is put directly behind each of the squares. A transparent or translucent picture would then be placed or drawn on each of the squares. When the small lamp behind the square was illuminated, it would create a bright spot in the middle of the picture, drawing, etc., (See Figure 14). This technique could be implemented with an LED, or with a small conventional light bulb such as a miniature version of a flashlight-type bulb. If an LED were used, one would have the same advantages of long life discussed above. The LED's in general, however, have a difficult time putting out enough light to be seen in daylight. Even the light bulb, however, has difficulty being seen in direct daylight unless it is drawing a considerable amount of power. The major advantage to this approach was seen to be a more direct indication of the picture, drawing, etc.

4. Full Back Lighting

The final approach is to completely light up the square which is being indicated (See Figure 15). This approach is probably the most straightforward and obvious means of indication and provides the child with a very fair indication of the indicated item. This technique, however, requires the use of a conventional light bulb since the LED's do not give off enough light to illuminate an entire square. This technique also draws quite a bit of power requiring a larger battery supply than the other approaches. Again, with this technique the pictures must be either transparent or translucent unless they are drawn directly on the communication aid.

5. Comparison of Indication Approaches

To test and compare the various approaches, a test setup was constructed which was capable of demonstrating each of the different methods. This setup was then used to gather information on the different approaches from teachers and clinicians.

Because this aid would also be used with very young and mentally retarded children, the corner light method of indication was not seen as

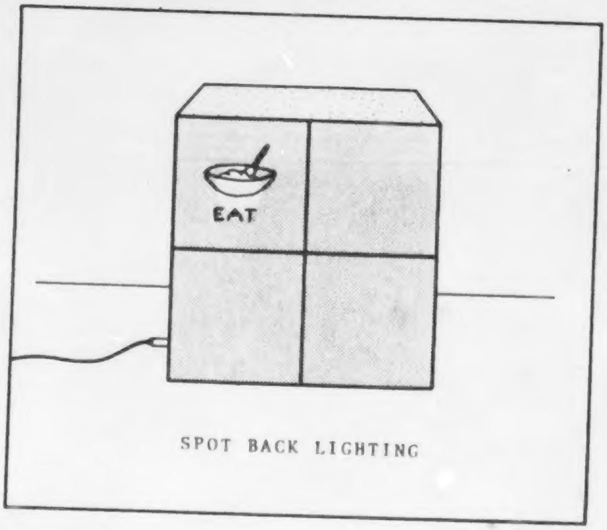

EAT
SPOT BACK LIGHTING

FIGURE 14

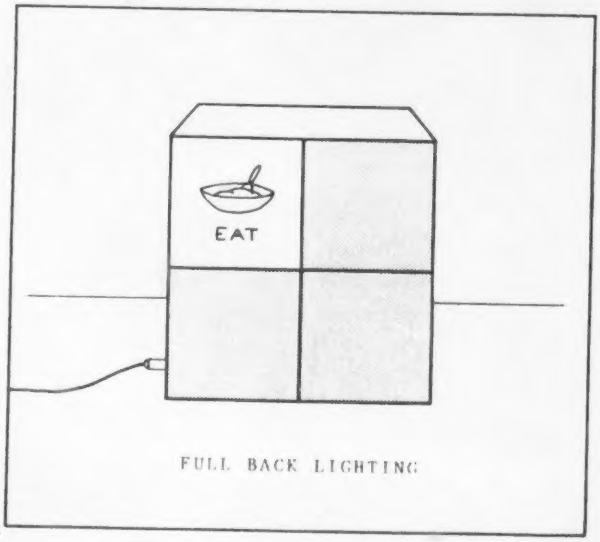

EAT
FULL BACK LIGHTING

FIGURE 15

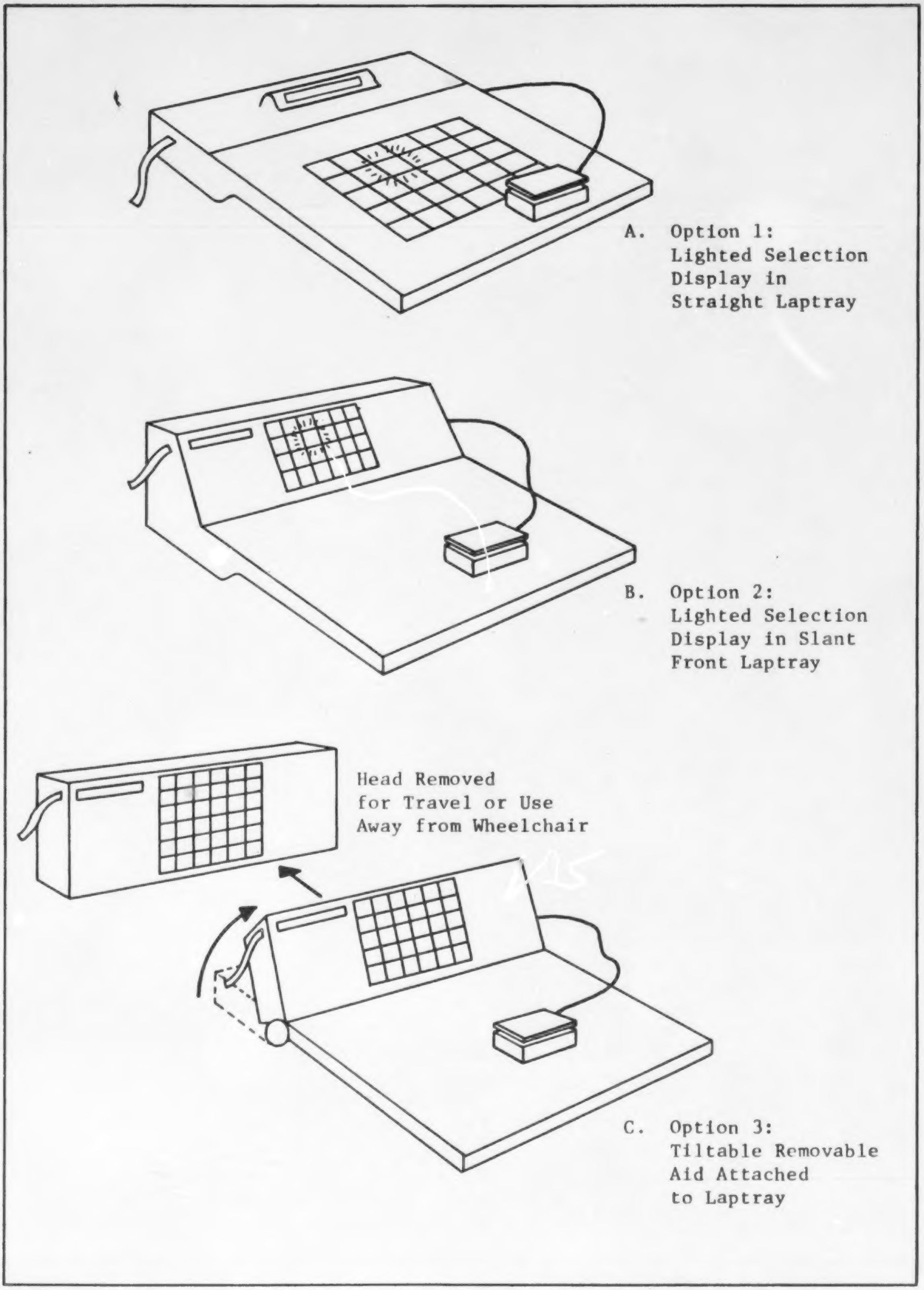
being appropriate by the reviewing field clinicians. It was thought that the concept of using a juxtaposition light to indicate a picture was beyond the skill level of some of the children with which the aid would be applied. Although the border lighting was seen as being better than the corner lighting, it was also judged to be not as appropriate as the back lighting approaches. Of the 4 approaches, the full back lighting approach was by far the most desired and recommended approach by the field clinicians and teachers. The spot back lighting was not as heavily endorsed, but has design and power advantages that would probably make it worthwhile to also field test a version using this technique to provide comparative evaluation with the full backlighting approach.

Versicom Package Design

In the development of the Versicom package, three major approaches were considered (Figure 16). The first package considered was the same package used for the Autocom-E. With this package, the lighted selection matrix would be positioned in the center of the laptray area and covered with a sheet of plexiglass (Figure 16a). One advantage of this approach is that it would reduce the total package forms to one, since the Versicom and the Autocom-E could then use the same basic format. Some of the disadvantages for this approach were that glare was seen to be a larger problem than with approaches b and c. Also, the ability for direct or bright sunlight to wash out the display was greater with this approach than b or c. In addition, the positioning of the switch which the child would use to control the aid might actually interfere with the child's ability to see the display. Also, the viewing angle would be bad, requiring the user to sit in a poor posteral position.

The second approach considered also used a one-piece laptray. With this approach a raised tilted portion was placed at the front of the aid to provide a convenient angle of presentation and to move the display out of the middle of the laptray area. This overcame most of the shortcomings of the previous approach. Some of the disadvantages of this approach stem from the fact that the front portion would have to be 5 to 6 inches high in order for the display to fit. This tended to obstruct the vision of the child and was a hinderance to people working with the child. During design process for these aids, teachers and clinicians were consulted and expressed a preference for aids which provided a flat laptray, since this would facilitate feeding and working with the child. This approach also resulted in a thicker, more bulky aid which was less convenient for packaging and travel.

The third approach considered called for all of the electronics to be mounted in a rectangular box which would be attached to the front of a plain wooden laptray. This box would be mounted on hinge points so that it could be tilted up for most of the day to allow the child a clearly visible communication display. When not needed, it could be locked into the flat position for ease in eating and other activities. Since all of the electronics would be contained within the head (the



A. Option 1:
Lighted Selection
Display in
Straight Laptray

B. Option 2:
Lighted Selection
Display in Slant
Front Laptray

Head Removed
for Travel or Use
Away from Wheelchair

C. Option 3:
Tiltable Removable
Aid Attached
to Laptray

FIGURE 16

Three Major Approaches Considered for Versicom rectangular box) only the head would have to be transported back and forth to school each day (a second wooden laptray could be kept at home), thus simplifying transportation. This approach would also provide a more conveniently-sized package for an individual who was not in a wheelchair but who was using the aid as a semi-mobile communication aid for himself. The disadvantages of this approach mainly revolved around the additional engineering needed to develop the hinging mechanism. Because of the relative advantages, the third approach was chosen for implementation in the first prototype. The first approach, however, has sufficient merit that consideration is also being given to it during the final development and field testing process which is currently under way.

IV. POTENTIAL FOR A DIAGNOSTIC/EVALUATIVE COMMUNICATION AID

Because all of the communication aids discussed previously use the same basic components throughout, it is possible to develop a single aid which would have the capabilities of all of the aids in Figure 7 . Such an aid would be more flexible than would be needed for any particular child and would also involve unnecessary expense. Such an aid, however, might be useful in a clinical center as either an evaluation or training tool. For this reason, the development of such a universal communication aid was kept in mind during the development process of the Versicom and the Autocom-E aid. By using the Versicom head and adding a laptray containing an Autocom sensing board and an appropriate set of encoding switches (Figure 17) such an aid should be fairly easily realized. The development and construction of such an evaluation aid of this type is currently underway as a part of a cooperative research program with the Michigan State University Artificial Language Laboratory under the direction of Dr. John Eulenberg.

Continuing Efforts

The UCM aids program is continuing under funding from several sources. The continued development and field testing of the Versicom and the encoding portions of the Autocom-E are supported under Grant #G007601628 from the Bureau for the Education of the Handicapped (OE). The development of the Autocom capability for the Autocom-E is being carried out in conjunction with an Aids Availability Program at the University of Wisconsin. Through this program, 40 UCM based aids will be constructed on a cost basis for individuals and centers across the U.S. and Canada as part of an open evaluation program in early 1977.

Cooperative programs have also been set up with the Trace Center by other research groups. The Blissymbolics Communication Foundation and the National Research Council of Canada are having a portable Bliss Symbol Printing communication aid developed using the UCM to assemble and "draw" the symbols on 2 1/4 inch wide tape (Figure 3). The Artificial Language Laboratory at Michigan State has also established a cooperative program to explore the use of voice synthesis as an output form for portable independent communication aids. The Swedish Institute for the

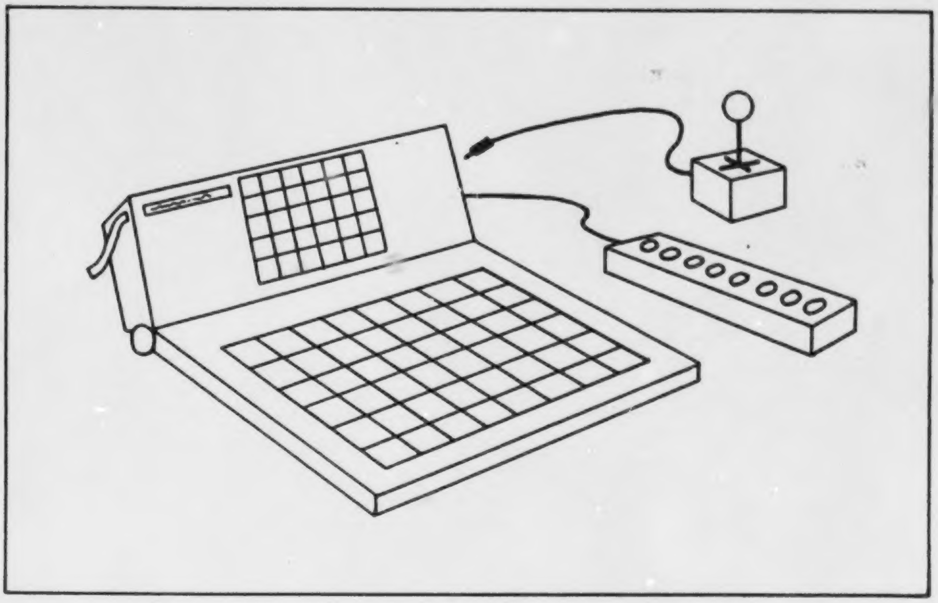


Figure 17. A Combination of the Versicom and Autocom-E for Use as an Evaluation and Training Tool

Handicapped (Handikappinstitutet) and the Royal Institute of Technology (Sweden) have also initiated discussion regarding cooperative research/development programs around the UCM aids.

Continuing efforts in this program area will be centered around identifying and further reducing major cost components of the system, increasing its flexibility and ability to meet the needs defined by teachers, clinicians and other researchers and increasing the aid's abilities to be developmental and grow with a child. It is hoped that by August 1977 the hardware designs of the UCM system can be frozen such that future developments/improvements can all be implemented in software. This will help ensure the same flexibility, maintainability and compatibility for all aids using the system and facilitate its use and further development by other groups.

V. SUMMARY AND CONCLUSIONS

To meet the needs of a broad range of severely physically handicapped individuals, a special control module for communication aids has been developed. This module, which can be packaged in different forms to meet specific needs, has been designed to allow for maximum adoptability both at the manufacturers and in the home/classroom to allow parents, teachers, clinicians, and handicapped individuals themselves to adopt the operation and functions of the aids to the specific needs of the individual. The system was also designed to allow its use in developmental aids which can take on a very simple form for a young child and then grow and expand its functions with the child's development of new skills and communication needs.

Two basic flexible aids have been developed using the control system and are currently being field tested in the United States and Canada. Other research groups are also having the module designed into special aids to meet their needs or to implement their ideas. Availability of these aids on a limited basis for additional field evaluation purposes is being provided by a special program at the University of Wisconsin-Madison. The selection of a manufacturer/marketer for the aids is currently underway and commercial availability of the aids is expected within the next two years.

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Interface Switch Profile and Annotated List of Commercial Switches

Trace Research and Development Center
For the Severely Communicatively Handicapped
University of Wisconsin-Madison

INTERFACE SWITCH PROFILE
AND ANNOTATED LIST OF COMMERCIAL SWITCHES

by

Craig Holt
David Buelow
Gregg Vanderheiden

December 1976

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Graphics: Jana Fothergill

Editor: Lynda L. Parker

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INTRODUCTION

The purpose of this preliminary profile is to provide a framework for identification of input switches and a list of commercially available switches. This report is part of a continuing effort at the Trace Center to locate, identify and describe different types of switches which can be used as interfaces between severely handicapped individuals and special communication and control aids.

The first of two sections is an annotated, illustrated profile of the different types of input interfaces. The set of switches on which this profile is based contains commercially available switches which are a part of a particular communication aid, switches that are commercially available by themselves and switches which have been custom designed for particular individuals. The second section is an annotated listing of commercially available switches which can be purchased by themselves. Included in this list will be suppliers' addresses and descriptions of the various switches which they offer. Information regarding estimated cost of and delivery time for the switches is also provided.

NOTE: Most communication aids can be operated by many of the switches listed in this report. However, if the aid and the input switch are bought separately or from separate suppliers, the input switch cord may require a new connector to make the cord compatible with the aid.

This is the first report of a continuous effort to locate and document the various types of switches which have been developed and those which are commercially available. As our research continues, we would like to encourage our readers to send to us any information known to them about switches not included in our report. Suggestions regarding content or format are also welcomed. For convenience, a form is included in the back of the report to facilitate reporting of new entries for the chart.

All communications should be sent to:

Trace Research and Development Center
for the Severely Communicatively Handicapped
922 ERB, 1500 Johnson Drive
Madison, Wisconsin 53706

SECTION I

PROFILE OF INPUT INTERFACES

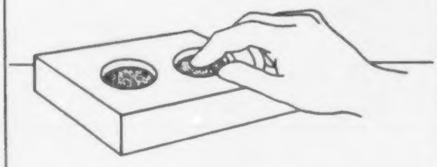
This profile is organized according to types of switches. Descriptions of each type are given, and in many instances descriptions and illustrations of examples of a particular type of switch are also provided.

PUSH SWITCHES

These switches are activated by physical pressure from some body part or from an implement such as a headstick. Examples follow.

1. *PUSH BUTTONS*

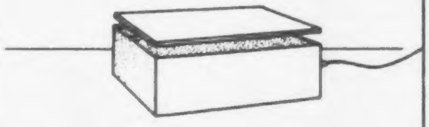
   There is a very wide variety of shapes and sizes. Some buttons protrude outward, while others are recessed to help prevent accidental activation. Usually used with fingers, fists, elbows, feet or a headstick.



PUSH BUTTON SWITCH

2. *PUSH PLATES*

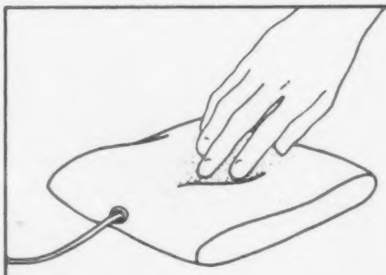
   Switching is accomplished by pressing anywhere on a large plate. A pivoted plate may be used to activate two different switches (See sketch.). Push plates usually consist of a stiff plate suspended above a push button.



PUSH PLATE SWITCH

3. *PILLOW, PAD AND STRIP SWITCHES*

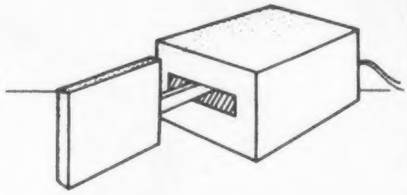
   These switches consist of a pressure-sensitive element wrapped in a soft or flexible covering. There are many sizes, shapes, sensitivities and materials -- from large foam-padded pillows to small plastic-covered strips. Some strip switches are activated by flexing as well as pressure.



PILLOW SWITCH

PADDLE SWITCHES

Paddle switches are activated by pushing or slapping a pivoting arm which extends from the switch mechanism. The paddle may move up or down or to the side and may be any shape, size or material.

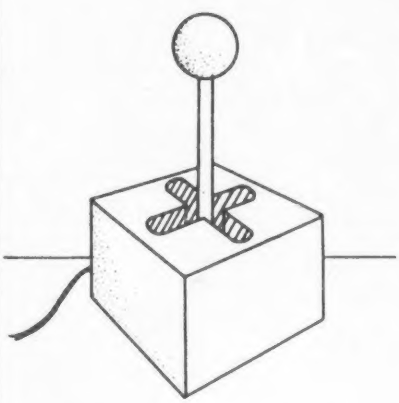


PADDLE SWITCH

JOYSTICKS, WOBBLESTICKS

1. *JOYSTICKS*

Multiple switches are operated by one control stick. In general, two to eight switches are incorporated. Various sizes and configurations have been designed for use by hand, finger, foot or chin.

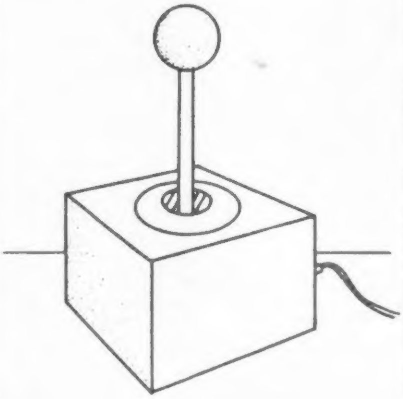


JOYSTICK SWITCH

2. *WOBBLESTICKS*

(Possum Controls, Ltd.)

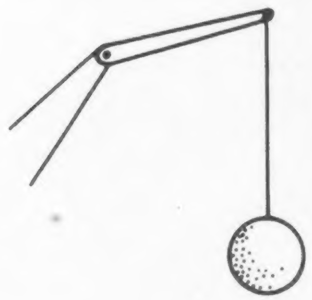
A wobblestick is a single switch activated by pushing the stick off center in any direction.



WOBBLESTICK SWITCH

3. *MED CALL BALL*

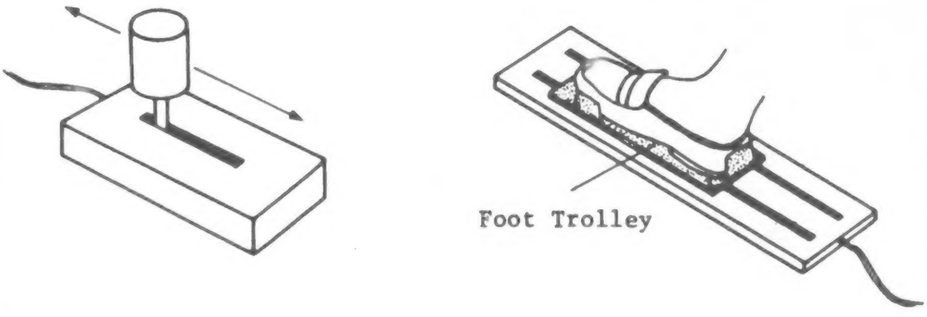
A variation is the MED Call Ball, a ball suspended from a cord. It is activated when the ball is swung off center in any direction.



MED CALL BALL SWITCH

SLIDING OR TROLLEY SWITCHES

Switching is accomplished by motion along a slide, groove or track. These switches usually have two positions ("on" at one end, "off" at the other) or two positions (one switch at each end, "off" in the middle).

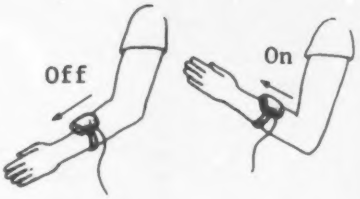


SLIDING SWITCH

TROLLEY SWITCH

TIP OR TILT SWITCHES

Tilted one way the switch is "off"; tilted the other way it is "on". The switch is strapped to the arm, head or any other body part which can be tilted or twisted.

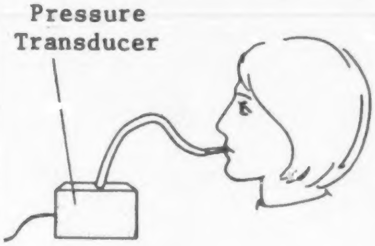


TIP OR TILT SWITCH

PNEUMATIC SWITCHES

1. *SIP AND PUFF SWITCHES*

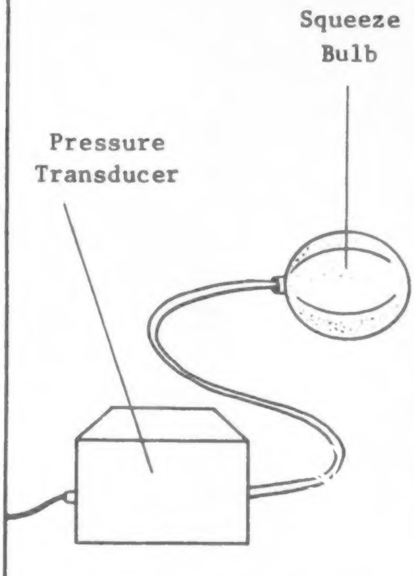
The switch is operated by very small pressure changes in the tube. Mouth control rather than respiratory control is usually sufficient to operate these switches.



SIP AND PUFF SWITCH

2. *AIR PILLOWS AND SQUEEZE BULBS*

The switch is activated by squeezing an air chamber of some kind. The aid pressure activates a pressure transducer just as in the sip and puff switch above.



SQUEEZE BULB SWITCH

PROXIMITY SWITCHES

1. *PROXIMITY SWITCH SENSITIVE TO BODY*

The switch is activated when a body part is brought within a certain range of the switch (capacitance or radar).

2. *PROXIMITY SWITCH SENSITIVE TO A SPECIAL TRIGGER ELEMENT*

The switch is activated when a special object (metal, magnet, circuit, reflector, etc.) is brought within a certain range of the switch.

MOTION-DETECTING SWITCHES

These switches are activated by motion within a certain range of the switch or along a certain beam (radar or infra-red).

EYE-CONTROLLED SWITCHES

1. *REFLECTED BEAM EYE SWITCH*

These switches are activated by looking in a particular direction. They usually direct a beam of infra-red light at the eye and detect the difference in reflection between the iris and the white of the eye. The detector apparatus can be mounted on the frame of a pair of glasses.

2. *BLINK SWITCHES*

Closing the eyelid for a certain amount of time activates the switch. The switch may work on a reflected-beam principle or with a mechanical switch.

3. *ELECTRO-OCULOGRAM*

Another approach is the use of the electro-oculogram (EOG) to determine eye position. This generally requires the placement of electrodes on the face, however.

OPTICAL SWITCHES

1. *LIGHTSPOT*

The beam from a light source (attached to the head or some other body part) is used to operate photosensitive switches on a panel in front of the user. The user can see the lightspot on the panel and maneuver it to the desired photosensor.

2. *INTERRUPTED BEAM SWITCH*

The switch is activated whenever a beam of light is interrupted (by an object or some part of the body). (Similar to electronic eye used with some automatic doors and alarms)

SOUND-CONTROLLED SWITCHES

1. *WHISTLE AND TONE SWITCHES*

The switch is activated by an audible or ultrasonic tone. The tone may be generated by an electronic module or mechanically as with a tuning fork or dog whistle. (When a whistle is used, it is usually connected to a squeeze bulb for ease of operation.) With this type of switch, no physical connection is needed between the user and the communication aid.

2. *VOICE SWITCH*

Voice switches are usually activated by a humming sound. Normal talking will not activate the switch.

The switch sometimes uses a microphone near the mouth or a vibration transducer attached to the throat to pick up vocal sounds.

BIO-ELECTRIC SWITCHES

These switches are activated by the electrical impulses generated in nerves and muscles of the body.

1. *MYO-ELECTRIC (EMG)*

Electrodes are applied to the skin near a controllable muscle group. Contraction of the muscle produces electrical signals which are detected by the electrodes and used to activate the switch.

2. *ELECTRO-ENCEPHALOGRAPHIC (EEG)*

Electrical activity in the brain is picked up through electrodes applied to the forehead, temples and/or scalp. Specific thought patterns are then recognized and used to operate a switch. (Switches in this category are still experimental in nature.)

SPECIAL SWITCHES FOR A SPECIFIC BODY PART

Some switch types, although they could be classified in the previous general categories, have been very specifically adapted to a particular part of the body. Some examples are listed below.

1. *EYEBROW SWITCH*

Operated by raising eyebrows (Veterans Administration).

2. *HEAD SWITCHES*

Switches can be built into headrests, etc.

3. *SPLINT SWITCHES*

A molded hand-splint with miniature paddle switches mounted above or below the fingers (Possum Controls, Ltd.).

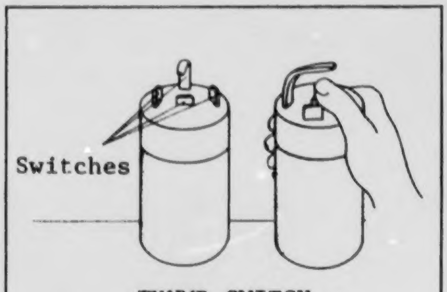
4. *TONGUE SWITCHES*

Specifically designed for operation by the tongue. Some are actually made to be worn inside the mouth.

5. *THUMB SWITCH*

(Fairchild-Hiller, "Viewcom")

This switch is operated by pressure exerted by the thumb on the buttons.



THUMB SWITCH

SECTION II

COMPREHENSIVE OVERVIEW OF COMMERCIAL SWITCHES AVAILABLE

In this overview, we have compiled a preliminary (inasmuch as our data gathering is ongoing) annotated list of commercial switches currently available (Table 1). Included in the data is the following information: 1) identification of the type of switch (e.g., push switches); 2) manufacturers or distributors; 3) physical description of the switch; 4) operation of the switch; 5) amount of pressure needed to activate the switch; and 6) cost and delivery time for the switch.

A list of manufacturers and distributors of the switches which were used in this report in contained in Table 2.

TABLE 1 - COMMERCIAL SWITCHES CURRENTLY AVAILABLE

Push-Lever Switches

*SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
		PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Two Way Hand Paddle	Ontario Crippled Children's Centre	Large clear plastic paddle about 8" long, mounted upright so that it can be pushed from side to side. Made to be bolted through laptray.	Two switches are operated by pushing paddle left to right.		Can be operated without the child lifting his hand from tray or table surface.	$50.	2-4 months
Tongue Switch (Toggle)	Prentke Romich Co.	Switch mounts in a 2" x 2" x 2" box at the top of a 19" adjustable metal gooseneck. Bottom of the gooseneck has mounting clamp.	Small Switch control bar is moved to one side by tongue, returns to center, neutral upon release. For 2-switch model, control bar can be moved in two directions.	1/2 - 1 oz.	Non-toxic rubber covering on switch control.	Single switch = $40. Dual switch = $45.	7-10 days
Hand Touch Call System	Fred Sammons, Inc.	Lever switch designed to attach to tubular bedrail. 10' cord.	Activates by pressing long narrow lever (about 3").	1 - 2 oz.		$14.95	1-2 weeks
Quad-Quip Head-Call System	Fred Sammons, Inc.	Lever switch mounted at the end of an 18" rod made to be clamped to a bed frame. A locking knob controls swiveling and height above bed. 10' cord.	Lever-type switch (about 3 1/2" long narrow lever activated by 1/2" motion.	1 oz.		$69.95	1-2 weeks

*Most communication aids can be operated by many of the switches contained within this table. However, if the aid and the input switch are bought separately or from separate suppliers, the input switch may require a new connector to make the cord compatible with the aid.

TABLE 1 (Continued)

	SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
			PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Push-Lever Switches	Head Control	Scientific Systems International, Inc.	Two switch pads mounted on gooseneck stands. Intended to be placed on either side of the head.	Two switches activated by pressing against a pad, (e.g., rotating the head from side to side).			$150.	4-6 weeks
Joystick and Wobblestick Switches	Joystick Assembly	Dufco	Joystick with about 1" diameter knob. Base size 7" x 13" x 2".	4-direction joystick with center off. Controls 4 switches.	3 - 4 oz.		$95.	1-4 weeks
	Hand or Chin	Maddak, Inc.	Joystick with soft rubber knob 7/8" diameter. Mounted on adjustable swivel which can position it at any angle and clamps to table, bed, etc.	4-directional joystick, center off.			$150.	2 weeks
	4-Way Joystick	Ontario Crippled Children's Centre	Joystick with aluminum housing.	4-direction joystick with fairly stiff handle motion. Base must be clamped down to a fixed object			$50.	2-4 months
	Med Call Ball	AAMED, Inc.	A 3" diameter round ball suspended from metal frame by a cord.	User slaps ball to activate switch. (Activated when ball swings away from center.)	Variable sensitivity.	Available with mounting bracket as extra.	$19.	2-3 days

TABLE 1 (Continued)

	SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
			PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Pushbutton Switches	Four Push Button Assembly	Dufco	Four raised pushbuttons arranged in diamond formation on 7: x 13" x 2" base.	Four pushbuttons	3 - 4 oz.			
	Hand Actuator Assembly	Dufco	Two buttons (1 1/4" diameter) on a single box 7" x 13" x 2".	Two pushbuttons	3 - 4 oz.		$60.	4-5 weeks
	Finger Control for Spastics	Maddak, Inc.	Four pushbuttons (3/4" diameter) on a single base 8" x 4" x 1-1/2".	Pushbutton			$150.	2 weeks
	Four Push Button Control	Maddak, Inc.	Four raised push-buttons on a single base.	Pushbutton			$75.	2 weeks
	Push Button Hand-switch	Vemaline Products Company	2" diameter push-button in industrial type heavy-duty metal housing about 2" x 4" x 3".	Pushbutton operation	3 lbs.		$11.10	1-4 weeks
Push-Plate Switches	Rocking Lever Switch	Prentke Romich Co.	Flat horizontal plate (about 4" x 1-1/2") mounted on a 4-1/2" x 2-1/4" x 1" box.	1- or 2-switch models. Switches are activated by pressing one side of a rocking plate.	1 oz.		Single switch = $25. Dual switch = $30.	2-3 days

TABLE 1 (Continued)

Push-Plate Switches

SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
		PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Surface Controls	Scientific Systems International, Inc.	Pressure-sensitive switch with broad activation area.	Operated by pressing on top surface.		Available in configurations designed for foot, elbow and hand.	Hand = $125. Elbow = $125. Foot = $175.	4-6 weeks
Galaxy Duft Foot Switch	Vemaline Products Company	Two pedals mounted on a single base 3-1/2" x 6-1/4" x 1/2" (Heavy-duty industrial type).	Each pedal controls two switches. Small pressure activates one switch. With added pressure, the second switch closes.	2 lbs.		$7.50	1-4 weeks
Jupiter Foot Switch	Vemaline Products Company	3-1/2" x 2-3/4" x 7/8" industrial type steel pedal with skid-proof basepad.	Pedal switch.	2 lbs.	Available in dual switch arrangement. Different colors available.	$3.05	1-4 weeks
Vanguard Foot Switch	Vemaline Products Company	4-3/4" x 4" x 1-3/4" cast iron pedal switch (heavy-duty industrial type).	Pedal operation	2 lbs.	Momentary or push-on, push-off.	$8.70	1-4 weeks

TABLE 1 (Continued)

SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
		PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Pressure Sensitive Pad	Ontario Crippled Children's Centre	Vinyl-covered foam pad.	Pressure activated.		One or more can be strung together. Different colors available.	$50.	2-4 months
Controflex Switching Mat	Tapeswitch Corporation of America	Pressure-sensitive mats 1/8" thick and 6" x 23", 17" x 23", 35" x 23".	Activated by pressure anywhere on mat.	5 lbs.		Minimum billing = $10. $6.40	4 days
Controflex Foot Switch	Tapeswitch Corporation of America	Flat sealed plastic strip 2" x 5" and 1/2" thick.	Activated by pressure anywhere on surface.	5 lbs.		Minimum billing = $10. $4.97	4 days
Flex Switch	Tapeswitch Corporation of America	Long narrow flexible plastic strip 9/10" wide and 1/8" thick. Available in 1' to 20'.	Activated by pressure of flexing anywhere along its length.	8 oz.		Minimum billing = $10. $4.09 for 1'.	4 days
Detector Cell	Tapeswitch Corporation of America	Small pressure-sensitive box 1'1/2" x 3/4" x 1/8" with foam rubber button disc .3" diameter mounted on it.	Pressure activated.	1 oz.		Minimum billing = $10. $5.27	4 days

TABLE 1 (Continued)

			DESCRIPTION			FEATURES & COMMENTS		
	SWITCH	COMPANY	PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE		PRICE	DELIVERY TIME
Pad, Pillow and Strip Switches	Easy Touch Contact Signal	Trujillo Industries, Inc.	A soft vinyl-covered disc 3/4" high and 3" in diameter. Cord is attached.	The switch is activated by applying light pressure to the surface of the disc.	2 - 7 oz.		$28.12	2 weeks
Pneumatic Switches	Air Switch with Bellows	Herga Electric, Ltd.	Plastic squeeze bulb or foot pedal. Bellows attached to switch housing by 6' flexible plastic tube. Switch housings are 3" x 3" x 2" or 3-3/4" x 5-5/8" x 2'1/4".	Several types of pressure-activated switches. Can be breath activated or different bellows can be attached for hand or foot operation.	Variable. Highly sensitive switches can be used without bellows (breath activated). Variable sensitivities down to .7" of water.	Switches, squeeze bulbs and housings ordered separately.		
	Puff and Suck Switch	Maddak, Inc.	A plastic mouthpiece on the end of two metal 24" tubes.	Controls four switches by means of two air tubes. Each tube controls two switches, one activated by inhaling, one by exhaling.			$235.	2 weeks
	Pneumatic Switch	Prentke Romich Company	19" adjustable metal gooseneck of 3-3/4" x 4-3/4" x 2-1/4" box. Two-switch model has sip and puff switches.	Switch operated by air pressure.	1-1/2 H_2O	Available with 6" long saliva ejector attachment.	Single switch = $60. Dual switch = $75.	7-10 days

TABLE 1 (Continued)

	SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
			PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Pneumatic Switches	Breath Control	Scientific Systems, International, Inc.	Two breath sensors placed in front of and slightly to the side of the mouth.	Operated by puffing on the breath sensors.			$225.	4-6 weeks
	Inhale/ Exhale Control	Scientific Systems International, Inc.	Plastic tube mounted on a gooseneck (bed-mounted) or headset (head-mounted).	Controls two switches. One switch is activated by inhaling, one by exhaling.			$150.	4-6 weeks
Zero Pressure Switches	Touch Controls	Scientific Systems International, Inc.	Two sensor areas mounted in a single molded base.	Switches are operated by touch.	0 oz.	Available in a configuration designed for elbow or hand.	$150.	4-6 weeks
	Four Touch Button Actuator Assembly	Dufco	Four touch buttons on 7" x 13" x 2" base.	Activated by skin moisture.	0 oz.		$90.	4-5 weeks
Eye Controlled Switches	Eye Control Switches	Scientific Systems International, Inc.	Eye position detector is mounted on an eyeglass frame.	Small light sources on the eyeglass frame shine on the white of the eye and are reflected back to a detector. When the eye is rotated upward and outward, the beam is broken by the iris, thus activating the switch.	N/A		$200.	4-6 weeks

TABLE 1 (Continued)

Voice Controlled Switches

SWITCH	COMPANY	DESCRIPTION			FEATURES & COMMENTS	PRICE	DELIVERY TIME
		PHYSICAL DESCRIPTION	SWITCH OPERATION	SWITCH PRESSURE			
Audio Control	Scientific Systems International, Inc.	A cylindrical transducer (about 1" diam.) is strapped around the neck.	Two switches, each activated by humming a different pre-selected tone.	N/A		$200.	4-6 weeks

TABLE 2

MANUFACTURERS AND DISTRIBUTORS OF SWITCHES

AAMED, INC.
1215 S. Harlem Ave.
Forest Park, IL 60130 (312)-626-1500

DUFCO
901 Iva Court
Cambria, CA 93428 (805)-927-4392

FRED SAMMONS, INC.
Box 32
Brookfield, IL 60513 (312)-246-3216

HERGA ELECTRIC, LTD.
Northern Way
Bury St. Edmunds
IP32 6NN, Suffolk ENGLAND (0284)-5772

MADDACK, INC.
Pequannock, NJ 07440 (201)-694-0500

MOTORETTE CORP.
6014 Reseda Blvd.
Tarzana, CA 91356

ONTARIO CRIPPLED CHILDREN'S CENTRE
350 Rumsey Road
Toronto, Ontario
M4G IR8 CANADA

PRENTKE ROMICH COMPANY
RFD 2, Box 191
Shreve, OH 44676 (216)-567-2906

SCIENTIFIC SYSTEMS INTERNATIONAL, INC.
506-B Oakwood Ave., N.E.
Huntsville, AL 35811 (205)-534-8272

TAPESWITCH CORP. OF AMERICA
320 Broad Hollow Road
Farmingdale, NY 11735 (516)-694-6312

TRUJILLO INDUSTRIES, INC.
5726 W. Washington Blvd.
Los Angeles, CA 90016 (213)-933-7469

VEMALINE PRODUCTS COMPANY
Wyckoff, NJ (201)-891-3200

DESCRIPTION OF INTERFACE SWITCH FOR ADDITIONS OR CORRECTIONS TO TRACE CENTER SWITCH SUMMARY REPORT

Name of Switch ____

Company that Produces Switch ____________________________

Address of Company and Person to Contact (if applicable)

____

____

____

(You may stop here if you wish, and we will secure the following information from the company.)

- -

Is the switch purchasable by itself? *Yes* *No* *(circle one)*

Cost ____________

Delivery Time ____________

Description of Switch

Physical Description ________________________________

____

____

____

Operation ____

____

____

____

Switch Pressure (if applicable) ______________________

____

____

Thank you

SYNTHESIZED SPEECH AS A COMMUNICATION MODE FOR NON-VOCAL SEVERELY HANDICAPPED INDIVIDUALS

Gregg C. Vanderheiden

Trace Center

Trace Research and Development Center
For the Severely Communicatively Handicapped
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SYNTHESIZED SPEECH AS A COMMUNICATION MODE FOR NON-VOCAL SEVERELY HANDICAPPED INDIVIDUALS

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June 1976

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For the Severely Physically Handicapped
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I. INTRODUCTION

With the employment of special communication aids to help non-vocal severely handicapped children and adults, the possibility of providing artificial speech for those who were not able to speak themselves has come under consideration. Recent advances in voice synthesis have brought this possibility closer to becoming a reality than ever before.

The problem of using voice synthesis as an output to communication aids, however, is not as simple as it might first appear. One cannot simply replace the printed output of a printing communication aid with vocal speech. There are problems with pronunciation, accent and inflection to deal with, in addition to the problem of teaching phonetic skills to non-vocal individuals. There are also many advantages to printed output that might make voice output a poor competitor, although it might be a valuable supplemental output form.

The purpose of this article is to explore some of these considerations and to describe some of the aspects and problems involved in developing vocal output mechanisms through the use of speech synthesizers. This information is directed toward teachers/clinicians in an attempt to provide them with a basic understanding of the possibilities and current limitations of voice synthesizers. It is hoped that this article can also provide them with a basic introduction so that they may provide further input to researchers regarding the constraints and problems, as well as the potential, for the use of synthesized voice as an aid to children in their classrooms, etc.

II. TYPES OF AUTOMATED SPEECH

The four major types of automated speech are:

- stored speech
  1. recorded voice
  2. digitized voice
- synthesized speech
  3. continuously controlled voice synthesis
  4. "sound module" or "phonetic".

A. STORED SPEECH

The first two types are not synthesized speech, but are stored speech techniques. The first is most familiar as the "time lady" of the telephone company. Actual tape recordings are made of a person's voice, which are then played back when needed. This technique allows for very intelligible, natural speech. It does present serious problems in accessing the appropriate words. Fast-winding the tape back and forth can be very time consuming. Thus, this approach is usually used only when there is a limited or predictable series of prerecorded messages.

The second approach also makes use of a human voice which, in this case, is stored electronically, rather than on tape. This is accomplished by taking a series of samples of the speech, converting them to digital numbers and storing them. (Hence the term, digitized speech.) Figure 1 illustrates this process. Because the waveform has been turned into a string of numbers, it can easily be stored in digital (computer) type memories. When the particular voice waveform (word, sentence, etc.) is desired, the number string can quickly be retrieved from the memory and used to reconstruct the original waveform, using the reverse of the process shown in Figure 1. Digitized speech has the advantage of high speed and intelligibility/naturalness. The high speed is a result of being stored in digital memories which allow for almost instantaneous retrieval. The naturalness comes from the fact that the speech is simply natural speech stored in a digital form. It can, therefore, be made to sound exactly like the original speaker. To achieve this naturalness, however, a large number of samples is required, and many numbers must be stored for each waveform. The disadvantage of this system is the amount of memory required to store the speech sequences. This technique is usually used only for small sets of words or phrases, since any large-scale storage of words would be cost prohibitive.

B. SYNTHESIZED SPEECH

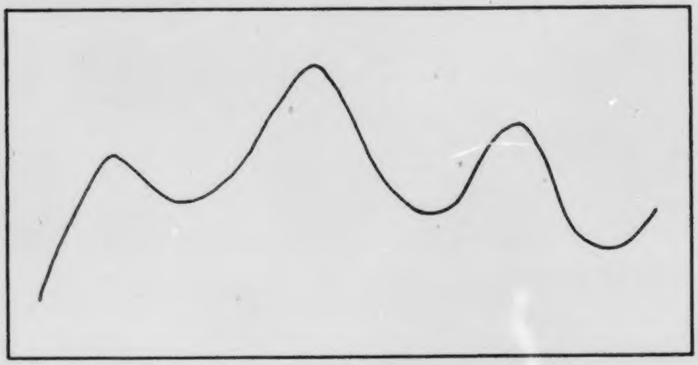
Whereas the two types of "stored speech" described above start out with a human voice which is then stored, actual synthesized speech does not make use of any human speech but is created by the speech synthesizer. Thus, a synthesizer is actually a machine which is talking according to instructions it has been given, rather than a machine which is playing back speech which it has previously recorded.

Because the synthesizer creates its speech output, it must be able to imitate all the resonant characteristics of the oral speech mechanism. The degree to which it fails to do this results in the unnaturalness and perhaps the unintelligibility of the resultant speech output. Trying to reproduce the complex oral speech mechanism electronically is an extremely difficult task, and much effort has been put forth in attempts to do so. The results of these efforts in terms of the quality of current synthesized speech will be discussed later in this article.

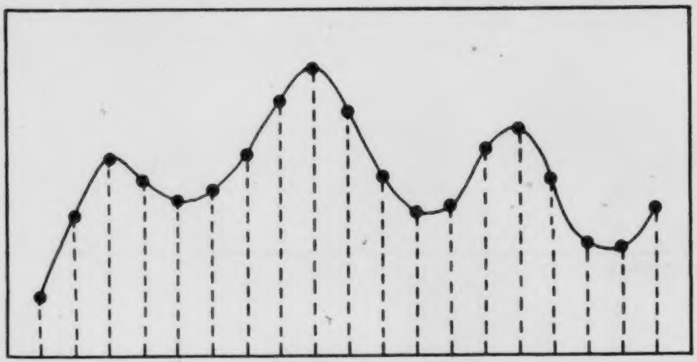
Two general categories of synthesizers currently exist. The first type is called the "continuous control" synthesizer. This synthesizer attempts to model the oral speech mechanism itself. Different variables in this model can be controlled by a computer. To create speech, the computer constantly changes the variables of the speech synthesizer in somewhat the same manner as a person would change the characteristics of his oral speech mechanism (by moving his tongue, lips, etc.) continuously as he speaks. The quality of the synthesized speech is therefore dependent on the success with which the synthesizer is able to model the oral speech mechanism. In general, this type of synthesizer has produced the best quality synthesized speech to date. It does, however, require the use of a large, fast computer. This would not preclude use of this

FIGURE 1

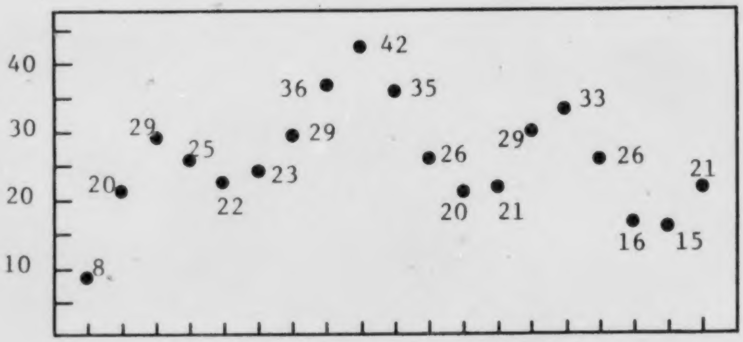
DIGITIZED SPEECH PROCESS



Voice Wave Form



Sample Times



Samples Given Number Value

8	20	29	25	22	23	29	36	42	35	26	20	21	29	33	26	16	15	21

Wave Form Stored as a String of Numbers

approach in a large number of applications for the handicapped, but it does limit its usefulness in portable communication aids for the non-vocal.

The second general type of synthesizer works with sound modules similar to phonemes. The synthesized speech is produced by stringing a set of these sound modules together to form the desired word, phrase, or sentence. One set of such sound modules is shown in Figure 2 (Votrax keyboard). To produce the word "hello" using this set, the user would hit "H", "EH", "UH", "L", "O" and then the output key "out." To add inflection with this system, one of four keys (INF 1 - INF 4) can be pressed simultaneously with the "phoneme" keys to put one of four levels of inflection on that "phoneme."

The synthesizer has preprogrammed instructions for producing each of the sound modules or "phonemes" as well as instructions for blending endings with beginnings of subsequent modules. This type of synthesizer has the advantages of simple output and the capability of being made quite compact. Because of these characteristics, this type of synthesizer shows the greatest potential for use as a communication aid for the non-vocal individual.

III. CONSIDERATIONS IN THE APPLICATION OF VOICE SYNTHESIZERS

A. VOCABULARY

Only a limited number of words can reasonably be stored and selected as words by the handicapped user. Since even a five-year-old child has a vocabulary of over 2,000 words, some sort of synthesizer which would allow the construction of new words easily by the user would generally be necessary to meet the communication needs of a non-vocal individual.

When considering voice synthesizers, it is therefore necessary to consider not only the aspects concerned with the selection of words or phrases for output, but also those aspects concerned with the construction of words from component parts. This has significant consequences in terms of speech, particularly when coupled with additional factors such as the need to specify inflection. It also raises questions concerning the ability of non-vocal individuals to construct words phonetically.

B. INFLECTION

Speech inflection is an important aspect of synthesized speech. Inflection is a problem that has not been considered previously with non-vocal communication aids because the output is usually printed. When the message receiver reads the message, he usually adds his own inflection without thinking about it. With vocal output, however, it becomes necessary for the handicapped individual to add any inflection that is to be present in the final message. This inflection includes both a component involved in the pronunciation of a word and a component which results from

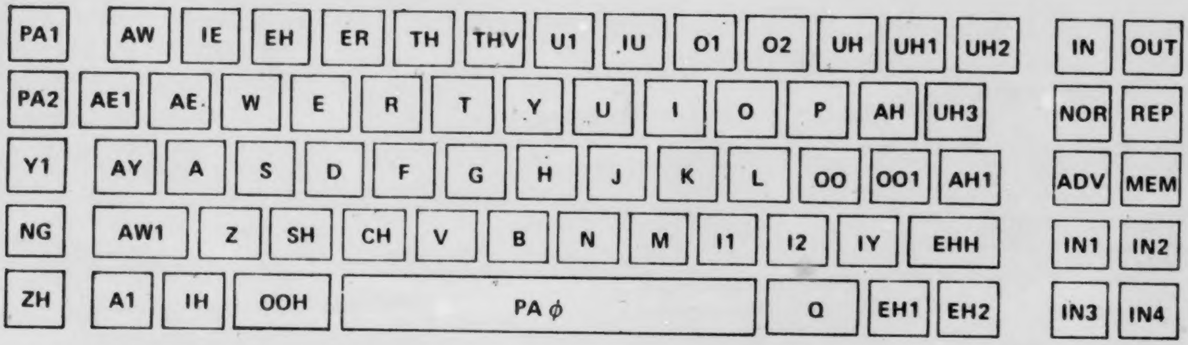

PA1
AW
IE
EH
ER
TH
THV
U1
IU
O1
O2
UH
UH1
UH2
IN
OUT
PA2
AE1
AE
W
E
R
T
Y
U
I
O
P
AH
UH3
NOR
REP
Y1
AY
A
S
D
F
G
H
J
K
L
OO
OO1
AH1
ADV
MEM
NG
AW1
Z
SH
CH
V
B
N
M
I1
I2
IY
EHH
IN1
IN2
ZH
A1
IH
OOH
PA ϕ
Q
EH1
EH2
IN3
IN4

FIGURE 2

VOTRAX KEYBOARD

the location of the word in the sentence, the structure of the sentence and the emphasis of the sentence. Straight monotone synthesized speech sounds bizarre and mechanical, and it is difficult to understand speech which has even a simple sing-song inflection.

Adding inflection to a word as it is constructed may double the time needed to construct the word. This may also be extremely difficult for a non-vocal individual unless he has a well developed inner speech which he can hear.

Even words that are available to the individual as whole words need to be further inflected to reflect their position and emphasis in a given sentence. Since the inflection of a word may change significantly depending on its position in a sentence, this reinflection of the word may take as much time as construction of a new word (without inflection).

Because of the complexity and number of rules that determine the inflection of the various words in a given sentence, automated inflection is difficult. Some significant progress has been made in the development of automatic inflection programs (NASA) for use with synthesizers such as the Votrax, but much work is needed before these programs will begin to produce normal inflection patterns for sentences. Currently the only advanced auto-inflection programs are those for the continuous control type of synthesizer discussed earlier.

Once effective auto-inflection programs are developed, there remains the problem of simplifying them for use by very small-scale systems such as those found in portable communication aids.

C. ENGLISH TO PHONETIC TRANSLATION

One approach to providing vocal output from communication aids would be to have the user spell out his message using traditional spelling, and have the communication aid translate it into spoken English. Although some programs have been written to accomplish this, they are quite complex and usually require a large number of direct pronunciation "lookups" because of the large number of exceptions in the English language. This approach does not lend itself well to the limited capabilities of a communication aid.

A second approach would be to use a modified spelling, wherein words would be spelled phonetically. For instance, the word "enough" would be spelled "enuf." This has the advantage of using the standard letters of the alphabet so that the individual can easily be provided with visual feedback as he constructs his sentence. It also has the advantage of using only 26 characters instead of a larger phonetic set of 64 characters, such as is used in the Votrax. A translation program to determine the pronunciation and to put it into the appropriate code for the voice synthesizer would still be required, but it could be much simpler.

A third approach would be to have the individual directly program the voice synthesizer, using the phonetic codes of the voice synthesizer. For a system such as the Votrax, described earlier, this may be quite straightforward. For other types of synthesizers with a more complex input form, some type of interpretation program using one of the above two input techniques may be more appropriate.

D. PRODUCTION OF PHONETIC-BASED OUTPUT BY NON-VOCAL INDIVIDUALS

Some concern has been voiced over the ability of non-speaking individuals to use successfully a system which relies so heavily on phonetic input. It has been pointed out that many non-vocal individuals have poor phonetic skills, and the presence of an inner voice which can allow them to sound out words is questioned.

While these individuals may have poor phonetic skills due to their lack of speech, the use of a synthesizer may help facilitate their phonetic skill development. Further, it may facilitate the development of an inner voice. Little is known in this area, and some good pilot research is needed. Many of these individuals are, however, able to learn to spell using the irregular semi-phonetic rules of English. It seems appropriate to assume that these same skills might be utilized to learn how to spell phonetically using the synthesizer. Further, it seems logical that a regular, phonetic system for spelling might even be easier than traditional English.

It would also be interesting to provide a young non-vocal child with a synthesizer and see whether through babbling or structured vocal imitation he would be able to learn to talk using one of these synthesizers without actually trying to learn to spell out the words.

E. CONSIDERATION OF SPEED

As with all communication aids, the speed of communication is an important factor. The rate at which an individual communicates and, consequently, the amount of time required of the second individual, is directly related to the communication opportunities and effectiveness of the handicapped individual. Although voice synthesis occurs at approximately the same rate as speech, the program of the message into the synthesizer takes just as long as if the aid were actually printing out the message. Using a Votrax, for instance, it takes almost exactly the same number of "phonemes" to program the synthesizer to say a message as it does letters to spell out a message using traditional English (Table 1). (Adding inflection to the message, however, could double the time it takes to program the message--assuming one-hand operation--since the inflection for each phoneme must be programmed in as well.) (Table 2). When one considers the fact that the previous sentence could take as long as 11 minutes for an athetoid CP child to program into the synthesizer (at one phoneme or inflectional value every two seconds), the effect of the slow speed upon a conversation is

TABLE 1

SPELLING VS. VOTRAX PHONEME SPELLING

English Orthography (373 keystrokes)

I am speaking to you through a voice synthesizer called VOTRAX. Let me give you a further example of my virtually unlimited capabilities.

"Four Score and seven years ago, our fathers brought forth on this continent a new nation, conceived in liberty and dedicated to the proposition that all men are created equal." One, two, three, four, five, six, seven, eight, nine, ten."

Votrax Without Inflection (322 keystrokes)

AH1, E1, AE, M, S, P, E, K, I1, NG, T, IU, U1, Y1, IU, U, PA0, TH, R, IU, UI, AI, AY, V, O1, EH3, E1, S, S, I1, N, TH, EH1, S, AH1, E1, 1Z, ER, K, AW, L, D, PA0, V, OO1, O1, T, R, AE, K, S, PA1, PA1, PA1, PA1, L, UH3, EH1, T, M, I3, E1, G, I1, V, Y1, I3, U, A1, AY, F, ER, THV, ER, I1, K, Z, AE, M, P, H3, L, PA0, UH1, V, M, AH1, E1, V, ER, DT, CH, IU, U1, UH3, L, Y, PA0. UH1, N, L, I3, EH3, M, EHZ, T, EH3, D, K, A2, AY, P, UH2, B, I3, EH3, L, EH2, T, E1, Z,

(PA1, PA1, PA1, PA1,)F, O1, R, S, K, OO1, O2, R, EH2, N, D, S, EH1, V, EH3, N, Y1, I3, ER, Z, UH2, G, UH2, O2, PA1, PA1, PA1, AH2, O2, R, F, AH1, THV, ER, Z, B, R, AW1, T, F, O1, R, TH, PA0, UH2, P, AH1, N, THV, I1, S, K, AH1, N, T, I2, N, EH2, N, T, PA1, A2, AY, N, IU, U, N, A1, AY, SH, EH2, N, PA1, PA1, PA1, PA1, K, UHZ, N, S, E, V, D, I1, N, L, I2, B, R, T, Y, PA1, PA1, AE1, N, D, D, EH2, D, I2, K, A1, AY, T, EH3, D, T, IU, U1, THV, UH2, P, R, AH1, P, UH2, Z, I2, SH, EH3, N, PA1, PA1, PA1, THV, AE1, T, PA0, AW, L, M, EH, N, PA1, AH1, UH3, R, K, R, E1, A, T, EH3, D, E1, K, W, UH2, L, PA1, W, UH, N, PA1, T, IU, U, PA1, TH, R, E, PA1, F, O, R, PA1, F, AH1, E1, V, PA1, S, I, K, S, PA1, S, EH1, V, EHZ, N, PA1, A, AY, T, PA1, N, AH1, E1, N, PA1, T, EH, N

TABLE 2

INCREASED LENGTH WITH MANUALLY INSERTED INFLECTION

Votrax With Inflection added manually (636 KEYSTROKES)

2/AH1, 3/E1, 2/AE, 2/M, 2/S, 3/P, 3/E, 3/K, 2/I1, 2/NG, 2/T, 2/IU,
2/U1, 1/Y1, 2/IU, 3/U, 1/PA0, 3/TH, 2/R, 2/IU, 2/U1, 2/A1, 3/AY,
2/V, 2/O1, 2/EH3, 3/E1, 3/S, 2/S, 3/I1, 3/N, 4/TH, 2/EH1, 2/S, 2/AH1,
2/E1, 1/Z, 3/ER, 3/K, 2/AW, 2/L, 1/D, 1/PA0, 2/V, 3/OO1, 3/O1, 2/T,
2/R, 1/AE, 1/K, 1/S, -/PA1, -/PA1, -/PA1, -/PA1, 2/L, 3/UH3, 4/EH1,
4/T, 2/M, 2/I3, 2/E1, 3/G, 3/I1, 3/V, 1/Y1, 2/I3, 3/U, 2/A1, 2/AY,
4/F, 3/ER, 2/THV, 1/ER, 2/I1, 3/K, 1/Z, 2/AE, 2/M, 2/P, -/UH3, 3/L,
1/PA0, 2/UH1, 2/V, 2/M, 2/AH1, 3/E1, 2/V, 4/ER, 3/DT, 3/CH, 1/IU,
2/V1, 2/UH3, 3/L, 3/Y, 2/PA0, 3/UH1, 2/N, 2/L, 4/I3, 4/EH3, 3/M,
1/EH2, 2/T, 4/EH3, 4/D, 2/K, 2/A2, 1/AY, 2/P, 2/UH2, 2/B, 3/I3,
3/EH3, 3/L, 2/EH2, 2/T, 1/E1, 1/Z,

(-/PA1, -/PA1, -/PA1, -/PA1)

2/F, 3/O1, 4/R, 2/S, 1/K, 2/OO1, 3/O2, 3/R, 2/EH2, 2/N, 1/D, 3/S, 2/EH1,
2/V, 2/EH3, 3/N, 3/Y1, 2/I3, 3/ER, 1/Z, 1/UH2, 2/G, 1/UH2, 3/O2,
1/PA1, 1/PA1, 1/PA1, 2/AH2, 2/O2, 3/R, 2/F, 2/AH1, 1/THV, 3/ER,
2/Z, 1/B, 2/R, 2/AW1, 3/T, 2/F, 2/O1, 3/R, 4/TH, 1/PA0, 2/UH2,
1/P, 3/AH1, 2/N, 2/THV, 2/I1, 1/S, 3/K, 3/AH1, 2/N, 3/T, 1/I2,
2/N, 2/EH2, 3/N, 4/T, 1/PA1, 3/A2, 1/AY, 2/N, 3/IU, 3/U, 2/N,
3/A1, 2/AY, 2/SH, 1/EH2, 1/N, 1/PA1, 1/PA1, 1/PA1, 1/PA1, 3/K,
2/UH2, 2/N, 2/S, 3/E, 4/V, 1/D, 2/I1, 2/N, 2/L, 3/I2, 3/B, 2/R,
2/T, 4/Y, 1/PA1, 1/PA1, 3/AE1, 3/N, 3/D, 1/D, 4/EH2, 3/D, 2/I2,
1/K, 2/A1, 2/AY, 2/T, 3/EH3, 4/D, 2/T, 3/IU, 2/U1, 2/THV, 2/UH2,
1/P, 2/R, 3/AH1, 2/P, 1/UH2, 2/Z, 4/I2, 1/SH, 2/EH3, 4/N, 1/PA1,
1/PA1, 1/PA1, 2/THV, 2/AE1, 2/T, 1/PA0, 3/AW, 4/L, 1/M, 2/EH,
4/N, 1/PA1, 2/AH1, 1/UH3, 2/R, 2/K, 2/R, 3/E1, 2/A, 3/T, 4/EH3,
2/D, 3/E1, 2/K, 2/W, 1/UH2, 1/L, 1/PA1, 2/W, 2/UH, 3/N, 1/PA1,
2/T, 2/IU, 3/U, 1/PA1, 2/TH, 2/R, 3/E, 1/PA1, 2/F, 2/O, 3/R,
1/PA1, 3/F, 2/AH1, 3/E1, 3/V, 1/PA1, 2/S, 3/I, 3/K, 3/S, 1/PA1,
4/S, 2/EH1, 1/V, 3/EH2, 3/N, 1/PA1, 2/A, 3/AY, 4/T, 1/PA1, 3/N,
2/AH1, 2/E1, 3/N, 1/PA1, 2/T, 2/EH, 4/N

apparent. The value of having automatic inflection programs which could cut the time in half, and the value of preprogramming commonly used words and phrases, can be seen. The fact that only a limited number of words and phrases can be effectively stored and accessed, however, will mean that normal communication will involve some individual spelling out of words not in the commonly used list. For example, a list of the hundred most frequently used words account for only % of the words in this paragraph, leaving approximately words which have to be spelled out.

An important point to keep in mind, therefore, when considering the advantages of synthesized speech as an output form for NVPH individuals, is that although it may provide some of the benefits of normal vocal speech, a rapid rate of communication is not necessarily one of them. It appears that speech synthesis would be no faster than the individual's ability to control a device which would print out his message for him. For mildly physically handicapped individuals, this could be quite rapid; but for the more severely involved individuals, this could still be relatively slow.

F. VOICE QUALITY

Although synthesized speech is readily identifiable as such, improvements have been made in recent years in terms of both intelligibilty and naturalness. The "continuous control" types of synthesizers are, of course, more intelligible, but even the "sound module" type of synthesizers are now producing highly intelligible speech. Synthesized speech usually sounds very masculine, somewhat raspy and machine-like, and often seems to have a slight accent.

To evaluate the voice quality from the viewpoint of a clinician and to explore the applicability of voice synthesis as an alternate output form for communication aids of NVSH children, 33 teachers and clinicians listened to the output of various synthesizers. The samples included a recording of a continuous control type of synthesizer from Haskins Laboratories and the output of the Votrax Model 5 voice synthesizer. They were instructed to write down their impressions and opinions of the synthesizers in the following three areas: 1) intelligibility; 2) voice quality; and, 3) applicability as a substitute voice for the non-vocal child.

The results of the evaluations are summarized in Table 3. In terms of intelligibility, the evaluators generally found the synthesizers to be good, with eleven using terms like good or great and only five making negative statements concerning the intelligibility. In discussing voice quality, most of the comments were centered around the fact that it was a very masculine voice and would be hard to associate with a young child. It would be quite adequate for use with an adult male. The voice quality was further described as being robot-like or mechanical, being better than some "deaf speech", but still not sounding normal, particularly in terms of the rate, phrasing and limited inflection.

TABLE 3 : SUMMARY OF CLINICAL EVALUATIONS OF BOTH VOTRAX 5 AND HASKINS LABORATORIES' VOICE SYNTHESIZERS

Number of similar comments	Comments on: INTELLIGIBILITY
6	"good"
5	"great"
2	"nasal phonemes distorted"
2	"easier to understand when used to it"
1	"surprising"
1	"better than anticipated"
1	"numbers ok, rest needs improvement"
	VOICE QUALITY
4	"hard to associate with child"
4	"need female and child voices"
4	"robot-like" or "mechanical"
3	"good for an adult"
3	"better than deaf voice"
3	"needs work"
2	"male"
2	"sounds like it has an accent"
2	"limited inflections"
2	"artificial rate, phrasing"
1	"would not be inhibiting"
1	"would be nice if it could vary to fit the individual"
1	"not unattractive, could get used to it"
1	"sounds dysarthic"
1	"useful in restricted setting (better familiarity with voice)"
1	"sounds normal"
1	"would get on nerves over time"
1	"easily recognized as non-standard"
	GENERAL
5	"would need average or high intelligence to use"
5	"further research should be done"
5	"more nearly approximates normal communication (than language boards, etc.)"
4	"would recommend for use"
4	"ability to 'produce' speech would be motivating"
4	"input skills might limit applicability"
3	"big improvement for the listener, no need to know the system"
3	"too expensive for the classroom"
2	"seems unnecessary with teletype for phone use"
1	"not applicable with retarded"
1	"much more personal communication"

In terms of general assessment of applicability with the handicapped, about half of the people made comments suggesting that it would have its application in its present form. The comments of the other half seem to indicate that they consider it more of an aid with future application. Even those who had seen it as having immediate application, however, say that further research and work on intelligibility and voice quality is necessary. A summary of the advantages and disadvantages of voice synthesis is presented in Table 4.

TABLE 4: SUMMARY OF VOICE SYNTHESIS ADVANTAGES AND DISADVANTAGES

ADVANTAGE	DISADVANTAGE
Vocal feedback	Does not satisfy written communication needs
More independent means of communication	Need to add inflection
More "natural" communication	Masculine - artificial voice from child
Regular phonetic vs. irregular English input	Need to input phonetically; lack of model in environment; need to learn two systems (phonetic and spelling)

G. VOICE VERSUS PRINTED OUTPUT

While voice synthesis can be a useful output form for communication aids, it is sometimes also thought of as an alternative to printed output from the communication aid. This application would eliminate some of the problems inherent in designing small portable printers, but it also removes an important aspect of communication: written communication. Much of our communication is in written form: letters, notes to others, notes to ourselves, etc. Because of the amount of time needed to assemble a message for non-vocal individuals, they often will be preparing messages in advance of when the message receiver is not present. For these reasons, they actually make much more use of note writing than would those with normal speech. Thus, voice synthesis may be more appropriately thought of as a supplementary form of output to a communication aid rather than as the sole output form.

IV. EFFECT ON THE DEVELOPMENT OF NORMAL SPEECH

One concern often voiced by teachers, clinicians and parents when discussing the application of non-vocal communication techniques is the effect these techniques will have upon the development of the child's own oral speech mechanism. The effect of using a speech synthesizer on the child's oral speech development is not known at this time. Research using other types of non-oral communication, such as communication boards and printing communication aids, however, has shown that the implementation of these non-vocal communication techniques has not impaired the development of speech in the children. In many cases, the use of other non-vocal techniques has increased the intelligibility and vocalizations of the children. Two reasons have been cited for the improvement in these children. First, by having a back-up system, the pressure is removed from the children in their attempts to speak. The children will often try to say the words first, and if they are not understood, they can then fall back on their non-vocal communication aid. Thus, the communication aid does not act as an alternative to speech, but as a supplement to whatever speech capabilities they may have.

The second reason cited for the increase in vocalizations and intelligibility of some of the children has been the increase in motivation to communicate, resulting from the successful communication experiences. By using a non-vocal communication technique when their speech is not functional, the children are able to communicate in environments, in situations, and on topics where they would not normally be able to communicate. Being successful in these instances, however, does not relieve the frustration of using the slower non-vocal technique instead of the faster mode of speech which is used by their peers and others in their environment. Their desire to communicate is, therefore, increased, and subsequently their efforts and progress in speech development may increase as well.

Since the use of a speech synthesizer would not be any faster than these other approaches, there is reason to believe that the same factors may enter into the picture in this case as well. The speech synthesizer may be more intelligible than their current communication, but it will never be as convenient, efficient, or as fast as oral speech. Therefore, it is unlikely that the use of the voice synthesizer in their present form would be a deterrent to the development of functional speech for those who are capable of developing it.

V. SUMMARY AND CONCLUSIONS

This paper has attempted to introduce some of the potential and some of the problems in the use of voice synthesizers as augmentative communication modes for non-vocal severely handicapped individuals. The fact that the voice synthesis can be thought of as a substitute for the printout of a communication aid has been advanced in an attempt to help demonstrate that many of the problems encountered in trying to teach a non-vocal physically handicapped individual to spell out his message would also be present in trying to teach an individual to control a voice synthesizer. Because of the vocal feedback, however, it may be easier for a child to learn to use the Votrax to "spell" phonetically than it is for the same individual to learn to spell using traditional orthography and the rules of English spelling. It was also mentioned that the speed of communication would be approximately the same for an individual controlling a voice synthesizer as it would be for one controlling a printout of some sort. In fact, with the problem of adding inflection, it may even be slower to communicate using the voice synthesizer. Thus, although the output of the voice synthesizer would resemble speech, it would not necessarily approach the speed of normal speech. For this reason, artificial speech would not be a competitor for the development of normal speech for those individuals who are, in fact, able eventually to develop their natural vocal mechanism.

The real potential for synthesized speech as a communication mode for non-vocal severely handicapped individuals is not known. Much research is still needed to solve some of the input problems to voice synthesizers, and to secure more clinical information on the actual application and acceptability of synthesized speech in the classroom, the home and the community. The clinicians and teachers who have heard samples of the synthesized speech, however, have been excited about its potential and about the progress that has been made so far. Advances both in speech synthesis and in technology in general are occurring rapidly and it may not be long before we will have answers to many of these questions.

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A FIELD EVALUATION OF THE AUTOCOM:

A Communication Aid for Non-Vocal Physically Handicapped Children

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December, 1975

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ABSTRACT

Educating a severely handicapped child who can neither speak nor write is a time consuming process and often may yield minimal results. The key to enabling effective education for these children lies in providing them with an effective means of communicating with and responding to their environment. With recent advances in physical and social sciences, communication aids and techniques which can help to overcome severe communication deficits, greatly reduce communication time, and provide completely independent expression are now being developed.

In order for teachers/clinicians to properly apply these aids, however, evaluative information is needed on the efficacy of the aids and their ability to facilitate the education of non-vocal, severely handicapped children. This paper documents the use of one such aid, the Autocom, with seven non-vocal cerebral palsied children and adolescents. One of the primary goals of this program was to investigate the effect of the aid on the students' acquisition of basic educational and communication skills. Specific areas that were facilitated were explored and capabilities of the aid which were most beneficial were documented. Weaknesses in the aids were also documented along with suggestions for design of better aids in the future. The overall results of the program indicated that aids of this type were of benefit to the educational process, though quantitative proof of this was not obtained from the study.

I. INTRODUCTION

A. PROBLEM STATEMENT

Recent legislation has insured that severely handicapped children, who have heretofore been left out of many educational programs, will be able to enroll and participate in appropriate learning and classroom environments. A current major concern among parents, educators and clinicians involves the ability of public and private school systems to meet the special educational needs of severely handicapped children. For many students and teachers, new educational and vocational opportunities will, initially, be very frustrating unless educational personnel are prepared to design effective programs which will provide these children with meaningful and productive learning opportunities.

One of the most difficult populations to include in formal educational programs will be non-vocal severely physically handicapped (NVPH) children. These children are unable to communicate except through gross gestures and pointing, and are unable to effectively interact with or transport themselves in their environment without the support of a variety of assistive aids. Although their physical disabilities and need for supportive therapies may preclude them from complete mainstreaming into regular educational classes, it is their inability to communicate which may preclude them from effective and meaningful participation in any instructional or learning environment.

Because of their inability to speak, and, in some cases, to gesture or point due to severe motor involvement, these children require extensive one-to-one instruction and are very dependent upon the close attention of others to interpret their needs and wants.

Currently, there are many different communication aids and techniques which can overcome severe communication deficits in non-vocal motorically impaired children (Vanderheiden, Harris-Vanderheiden, 1975) (Luster, Vanderheiden, 1975). These aids and techniques range from fundamental classroom constructed letter and wordboards to more advanced electronic portable aids. Although many of the aids are similar in concept or in operation, each is designed differently to accommodate different abilities on the part of the children. These aids and techniques, when appropriately applied and integrated into educational programs, can overcome the severe communication deficits of a great number of NVPH children. It is of critical importance, then, that educators and clinicians learn of these aids and become familiar with how and when to utilize them. They should be provided with information concerning the specific characteristics of each aid; the aid's applicability to various populations; its use and value in the educational and communication skill progress of the NVPH child; its effect upon the child's socio-emotional adjustment; teacher, parent and child reaction to use of the aid; and basic cost/benefit information on the aid.[1]

---

[1] Since many of the aids will be relatively expensive, the educator needs to become aware of those benefits which the aid will provide which cannot be attained through other methods.

These and other relevant concerns can be best answered through conducting field evaluations of communication aids. Field evaluations can provide information which will allow teachers and educators to judge the efficacy of a particular aid in providing a child with an efficient means of communication. Based upon this information, an appropriate aid can be selected for a child and thus allow him/her to meaningfully participate in newly acquired educational opportunities.

B. REVIEW OF PAST FIELD EVALUATION PROGRAMS

The only known systematic efforts to evaluate communication aids to date have been those conducted by the Cybernetics Research Institute (Kafafian, 1973), the Crotched Mountain Foundation (1966), Tufts Biomedical Engineering Center (Foulds, in progress) and the one to be described in this report.

The Crotched Mountain study was addressed to an evaluation of "the ability of cerebral palsied persons to manipulate and control a series of switches connected to various output devices" (1966). Success in the program was measured by the individual's ability to control one or more of a series of outputs through utilization of an appropriate switch. The Cybernetics Research Institute (CRI) included more observation of the use of communication aids for various classroom activities in their evaluation, but major focus was placed upon determining whether or not providing handicapped children with a prosthetic aid allowed them to achieve a "usable and effective written communication capability" (Kafafian, 1973). Neither of these studies addressed assessment of the educational and communication impact of providing an NVPH child with an effective means of communication. This aspect has recently been included in the Tufts study (Foulds, 1975) and is the primary focus of the field evaluation reported here.

In 1973, the Trace Center initiated a preliminary evaluation program, designed to field test the physical features of a direct selection aid (the Autocom) and to document educator and child reaction to this particular communication system. (NSF EC40316). At the initiation of this preliminary evaluation the Autocom, a stationary communication aid, was placed with nine non-vocal cerebral palsied children in southern Wisconsin and northern Illinois. Quantitative and qualitative information pertaining to the effectiveness, convenience, usefulness, and reliability of the aid were collected, and the stationary Autocom's appropriateness and overall value to the intended target population were judged. Overall, the results of this pilot test indicated that the stationary Autocom was successful in various educational environments and was shown to be of value to the educational and communication development of non-vocal, motorically impaired children. (Harris-Vanderheiden, 1975).

One of the major results of this field test, however, revealed that the Autocom would need to be made portable if it were to be an effective communication aid. All of the students in the study used the Autocom daily for educational purposes, but many found that, because it was stationary and could not be moved from room to room or from classroom to home, it was not effective as a communication aid. As a result of student, teacher and parent reaction to the stationary feature of the aid, a new portable version was developed. At the same time that the aid was being designed to be portable, it was also given the ability to print out whole words, phrases and sentences so that it could also be used by prereading children. The word printing capability also could speed up the relatively slow rate at which children must communicate on a spelling board. It was felt that the portable, word/letter printing version of the aid would be much more applicable as both a communication and educational aid to these children.

A continuation/expansion of the evaluation was then initiated in order to field test the portable Autocom, to continue research into the use and applicability of communication aids and generate longitudinal information on this topic, and to evaluate the overall effects and benefits of providing effective communication modes to non-vocal severely handicapped children.

It is this second, expanded evaluation which is documented in this report.

II. OBJECTIVES OF THE CONTINUED/EXPANDED EVALUATION PROGRAM (Conducted under this grant).

The overall objective of the evaluation program was to obtain additional information on the use of communication aids with school age children in order to:

a) provide teachers, parents, etc. with information necessary to select and apply communication aids most effectively and

b) provide researchers and developers with information which can assist in the development of better aids to provide these children with means of communicating, interacting and securing an appropriate education.

The evaluation program consisted of five areas of study designed to:

1) obtain quantitative and qualitative information on changes in the rate of acquisition of math, language and spelling skills with the introduction of an independent communication aid

2) compare a portable word/letter printing version of an aid to a stationary letter-only version of the same aid

3) study the effect of an independent aid on the child's adjustment and interaction at school and at home

4) examine and document the ways in which the aid was and was not able to be integrated into the existing curricula and classroom procedures

5) obtain information to assist in the design of better aids in the future

III. METHODS AND PROCEDURES

A. DESCRIPTION OF THE AIDS USED IN THE STUDY

The Autocom is a completely independent direct selection communication aid (Figure 1) which operates in much the same manner as the traditional communication board (Figure 2) except that a magnet is used to point to the various letters instead of a finger, knuckle, headstick, etc. A special magnet sensing system inside the lapboard tracks the position and movement of the pointer/magnet and prints out the letters (or words) as the user points to them. A variety of mountings of the cursor magnet (Figure 3) permits the use of the Autocom by persons of varying abilities.

The Autocom operates on what has been termed the auto-monitoring principle which combines a matrix of wide angle magnetic proximity switches with a delay activation mechanism. This combination produces a sensing system which is sensitive to reduction of movement rather than to discreet movements as in traditional switching arrangements. This insensitivity to erratic movements causes the aid to ignore small tremors as well as momentary loss of control due to spasms or overexcitement. The delay activation mechanism also allows the user to slide his hand around over the surface of the display board when moving between selections.

There were two types of Autocoms used in this study: an earlier stationary version which required spelling, and a later portable version which also had a work/phrase printing capability in addition to its spelling mode of operation.

The Stationary Autocom

The stationary Autocom was developed to allow a child to communicate without the aid of a second person. A special electronic circuit within the board monitors the sporadic movements of the child and determines the correct letter automatically (see Figure 4). Once the child selects a letter, the Autocom prints it on a display (see Figure 5). In this manner, the child is able to compose a message entirely on his own. A second person is required only to respond as he would to a vocal question or comments.

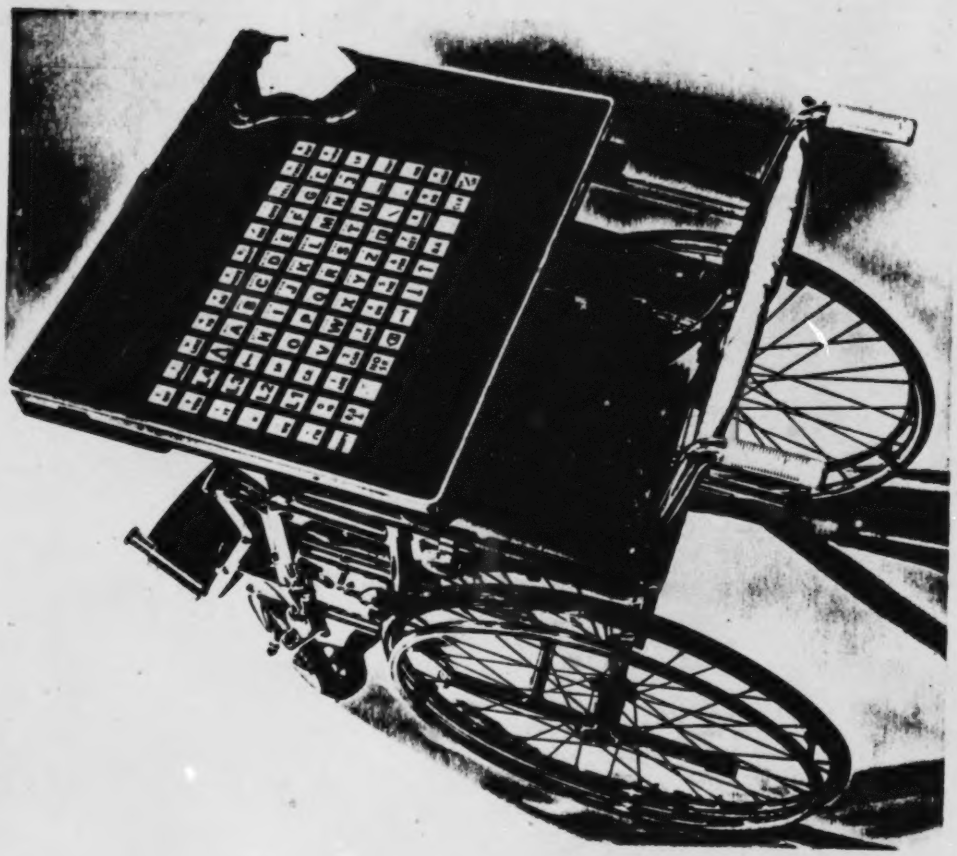


FIGURE 1

Portable Autocom on Wheelchair

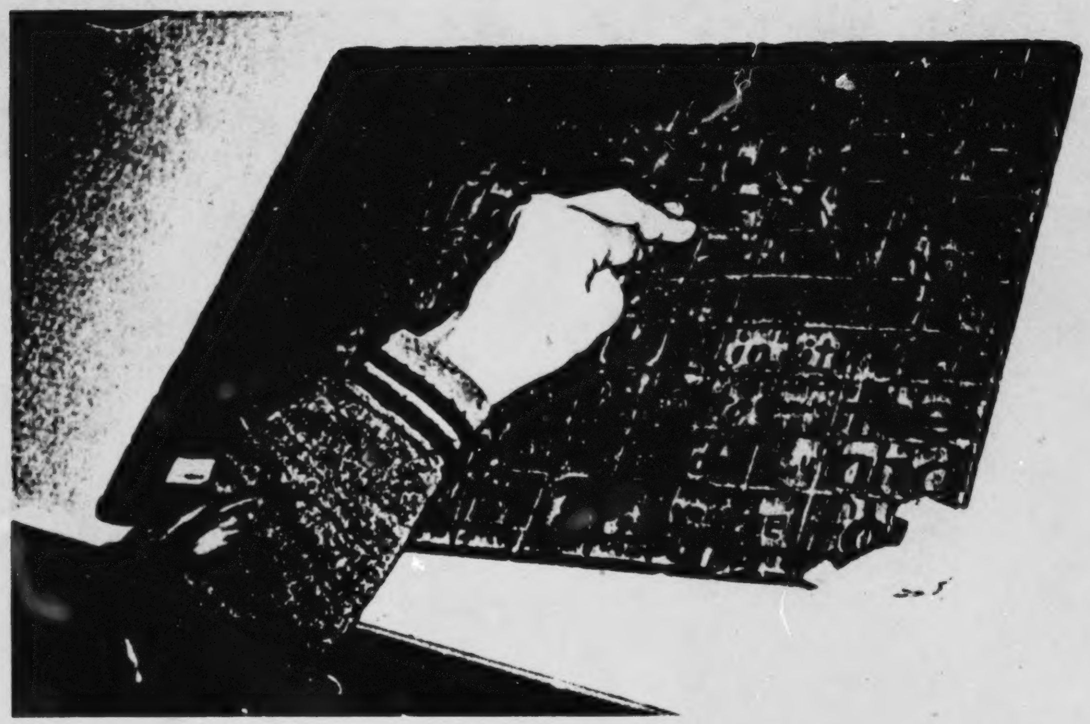
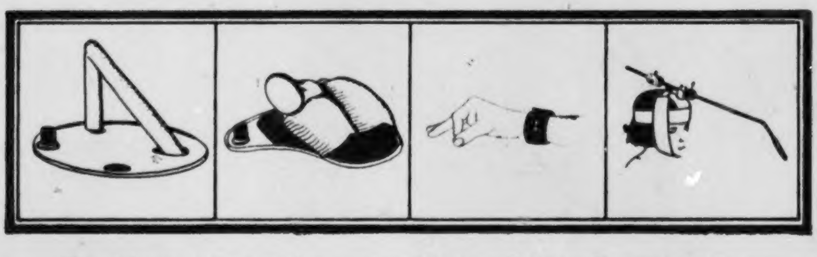


FIGURE 2

Communicator's Board



The pointer-magnet used to operate the Auto-Com can be mounted in many different ways to take best advantage of a user's specific abilities. Shown: clenched fist handpiece, molded handpiece, wristband and headstick.

FIGURE 3

Four Examples of Pointer-Magnets

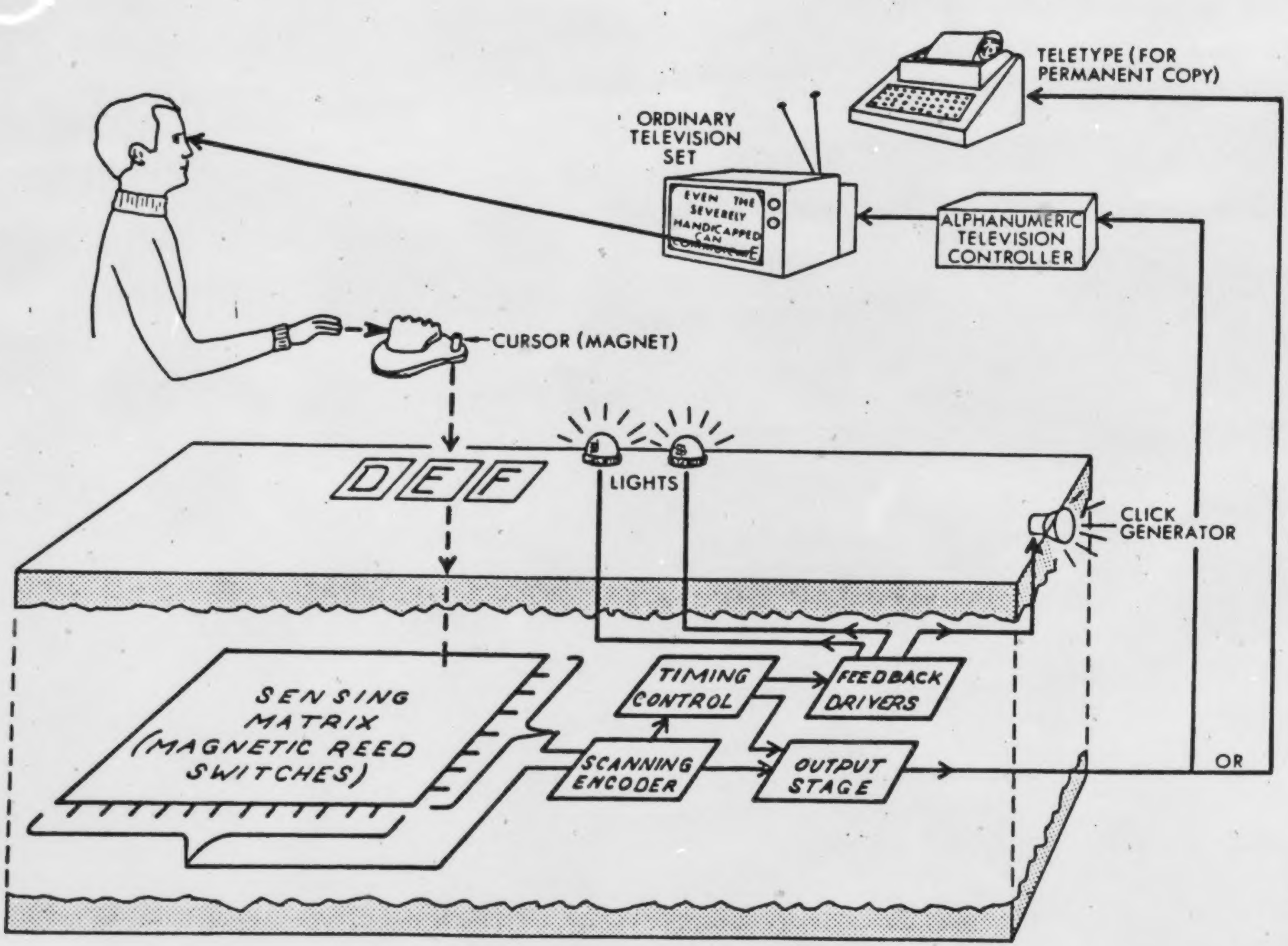

TELETYPE (FOR PERMANENT COPY)
ORDINARY TELEVISION SET
EVEN THE SEVERELY HANDICAPPED CAN COMMUNICATE
ALPHANUMERIC TELEVISION CONTROLLER
CURSOR (MAGNET)
D E F
LIGHTS
CLICK GENERATOR
SENSING MATRIX (MAGNETIC REED SWITCHES)
TIMING CONTROL
FEEDBACK DRIVERS
SCANNING ENCODER
OUTPUT STAGE
OR

FIGURE 4

Exploded Diagramatic View of Autocom System Showing Major Functional Blocks

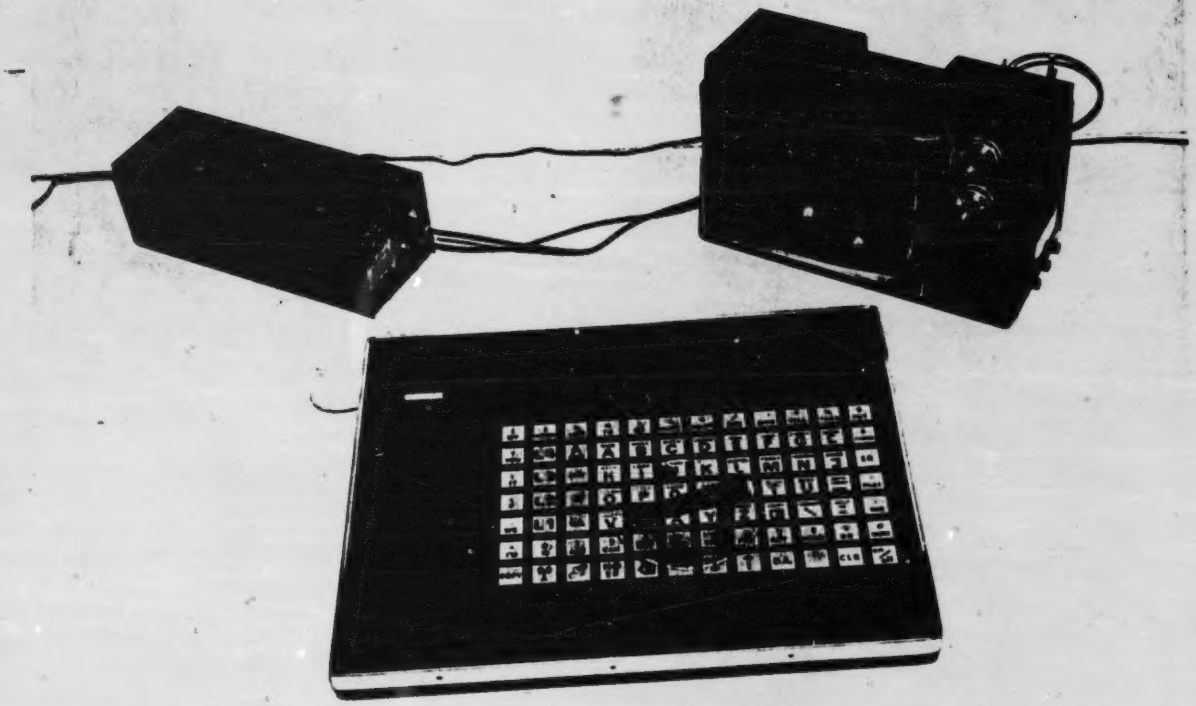


FIGURE 5

Autocom With TV Display

The Autocom setup used by most of the children in the study consisted of a stationary Autocom setup on a table in the classroom and connected to a television character generator/controller. The TV controller in turn was connected to a TV allowing the child to compose his message directly on the TV screen, correcting his mistakes as he went along (Figure 6).

Portable Autocom

The portable Autocom is operated in the same manner as the stationary model, but offers several additional features. Whereas the stationary Autocom must be plugged into a wall socket to operate, the portable model is built into a special wheelchair laptray and derives its power from rechargeable batteries. The portable Autocom controls the same output forms (television display, typewriter and teletype) as the stationary model and offers an additional strip printer which is built into the portable aid (see Figure 7). Because of the portability and built-in strip printer, a child need never be without a means of communication, since the aid can always accompany him and be operable.

Another added feature of the portable Autocom is the Wordmaster option, which allows the aid to print out whole words, phrases or sentences with a single pointing motion. The surface display of the stationary model consists of a letter-symbol matrix of 84 one-inch squares. The matrix includes the alphabet, numbers, mathematical symbols, punctuation marks, and special control squares. The portable model's Wordmaster option adds a set of commonly used words to this matrix (see Figure 8). In addition to the common words which are printed on the surface of the board, the portable Autocom has a snap-in memory cartridge which can be programmed with words, phrases and sentences chosen by the individual user. This option enables the portable Autocom to be introduced with very young children and also increases an individual's speed of communication.

B. DESCRIPTION OF STUDENTS IN THE EVALUATION PROGRAM

The students who participated in the continued evaluation program included seven[2] non-vocal, cerebral palsied students. Previous communication methods used by the students included gestures, gross pointing, limited vocalizations and, in several cases, letter or word boards. Teachers reported that guarded or masked typewriters were also tried, but all of the students lacked adequate physical skills required to effectively use this type of aid for communication purposes. Overall, the teachers considered their student's previous means of communication to be slow, tedious and frustrating.

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[2] Two students who were enrolled in the initial evaluation were not carried over into the continued evaluation. One child had developed severe scoliosis and became bedridden. The other child had developed sufficient motor skill to use a masked typewriter. Since he was sharing his Autocom with a more severely handicapped child, the school student preferred that the aid be available to the latter student full-time.

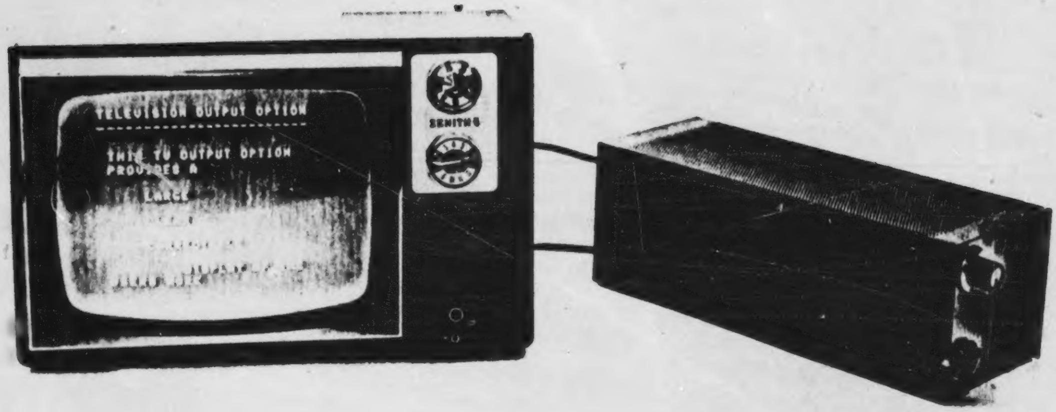
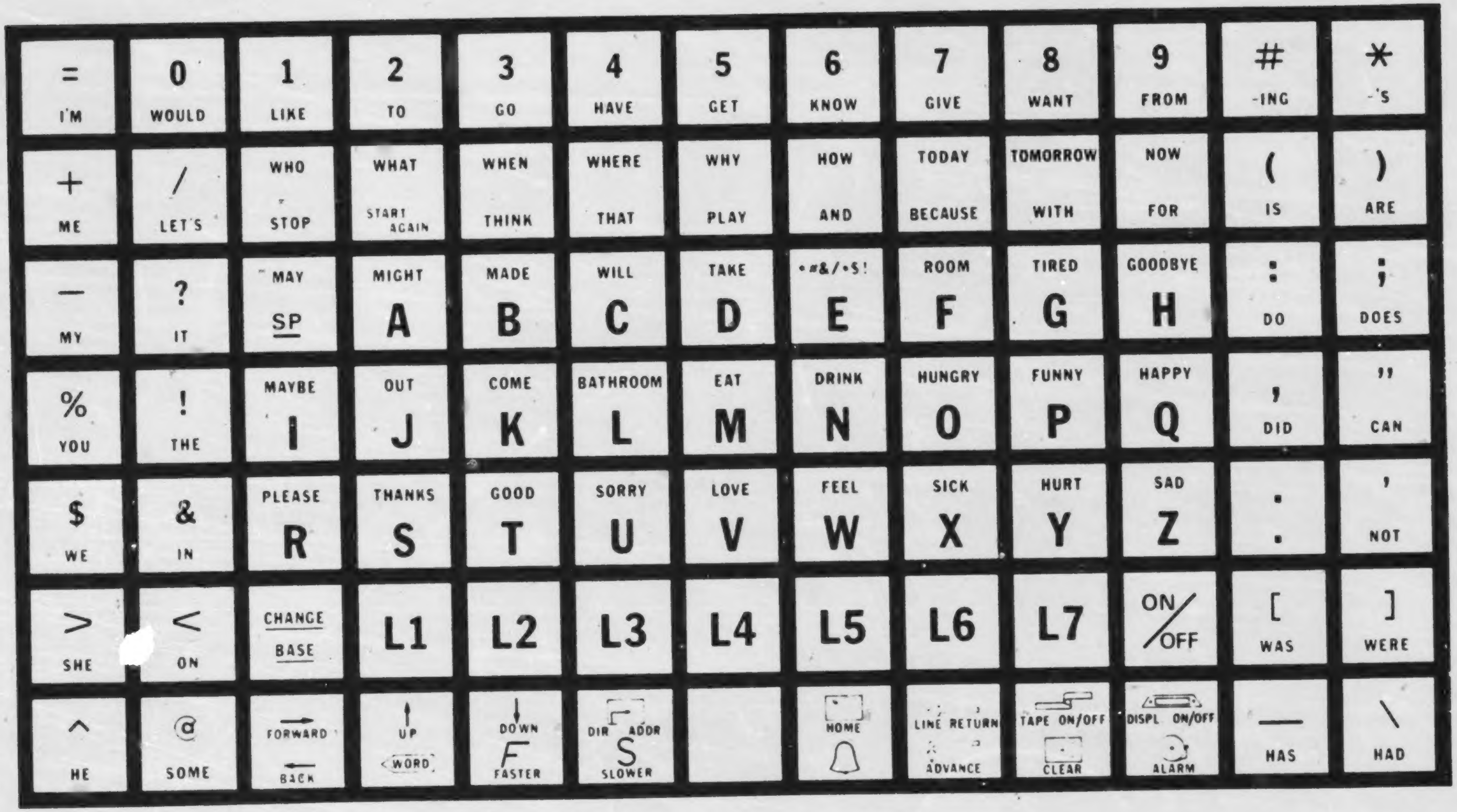

TELEVISION OUTPUT OPTION
THIS TV OUTPUT OPTION
PROVIDES A
LARGE
ZENITH

FIGURE 6: Correctable Display

FIGURE 7: Strip Printer Built Into Aid



= I'M	0 WOULD	1 LIKE	2 TO	3 GO	4 HAVE	5 GET	6 KNOW	7 GIVE	8 WANT	9 FROM	# -ING	* -'S
+ ME	/ LET'S	WHO STOP	WHAT START AGAIN	WHEN THINK	WHERE THAT	WHY PLAY	HOW AND	TODAY BECAUSE	TOMORROW WITH	NOW FOR	(IS	) ARE
— MY	? IT	MAY SP	MIGHT A	MADE B	WILL C	TAKE D	•#&/•$! E	ROOM F	TIRED G	GOODBYE H	: DO	; DOES
% YOU	! THE	MAYBE I	OUT J	COME K	BATHROOM L	EAT M	DRINK N	HUNGRY O	FUNNY P	HAPPY Q	, DID	" CAN
$ WE	& IN	PLEASE R	THANKS S	GOOD T	SORRY U	LOVE V	FEEL W	SICK X	HURT Y	SAD Z	. .	' NOT
> SHE	< ON	CHANGE BASE	L1	L2	L3	L4	L5	L6	L7	ON/OFF	[WAS	] WERE
^ HE	@ SOME	FORWARD BACK	↑ UP WORD	↓ DOWN F FASTER	DIR ADDR S SLOWER		HOME 🔔	LINE RETURN ADVANCE	TAPE ON/OFF CLEAR	DISPL ON/OFF ALARM	— HAS	\ HAD

FIGURE 8

Portable Autocom Display Board

Prior to original selection, each student was afforded a trial use of a stationary Autocom to determine whether he had the physical ability to operate the aid. Judgments and observations of the student's teacher, speech clinician, occupational or physical therapist, and parents were also heavily relied upon in order to determine whether or not the student required this type of an aid and would be able to operate it effectively. A final concern of the subject selection was the desire of the student and teacher to work with a new mode of communication.

The seven students in the evaluation program were non-ambulatory, cerebral palsied and lacked functional speech (see Table 1). One student, SMM, had limited speech, enabling her to verbalize short, intelligible utterances to individuals familiar to her. However, her speech was not functional for communicating with strangers. This student was included in the evaluation program in order to determine the usefulness of an Autocom system as an aid to augment partially intelligible speech and as a writing aid for this type of motorically impaired individual. The three male and four female students ranged in age from seven to nineteen years. Most of the students have been educationally diagnosed as "average or near average in intellectual ability." These diagnoses were based upon past academic records and teacher judgments. One exception was SKS, who was considered "severely learning disabled."

The types of educational environments of the students included a hospital school, a public elementary school, a public junior high school, and a public high school (see Table 2). Five of the classrooms were self-contained special education classrooms and two were resource rooms. The types of educational programs provided ranged from regular education for orthopedically handicapped children to programs for educably mentally handicapped children. Additional supportive services which were also available to most students included occupational therapy, physical theraphy, and speech therapy.

C. EVALUATION AND DATA COLLECTION PROCEDURES

The data collection procedures utilized in this study were designed to obtain descriptive, investigative information relating to the interaction of each student with the communication aid, the use of the aid at home and school, and educational programs and curricular materials used with and/or implemented for the aid. Methods and procedures implemented included the following.

1. Systematic Teacher Feedback System

Teachers served as primary observers and reporters for this evaluation program. Teachers were utilized in this capacity in order to more accurately evaluate the aid's applicability to educational environments. All but one of the field placements were outside the Madison area, with an average placement distance of 110 miles, which limited the opportunity for researchers to directly observe classroom

Table 1.

Summary of Students

Subject	Age as of 9/73	Sex	Neurological Description	Previous Communication* Method (prior to Autocom)	Date Receiving Autocom	Educational Environment
S_1 (CR)	6	F	Partial spastic, partial athetoid, able to walk with aid	Gestures and pointing, could not letterboard, attempted to use typewriter with one finger taped in a sling-was discontinued	12/19/73	Public School day care program for young multi-handicapped children, housed in a rural church facility
S_2 (MS)	8	F	Spastic, quadraplegic	Gestured by shaking head, pointing; picture and letter board	1/5/74	Residential Hospital School
S_3 (DC)	19	F	Primarily athetoid, some spasticity on left side, quadraplegic	Language board, gestures with eyes and pointing with hands	4/73	Public High School, Resource Special Education Classroom
S_4 (CC)	14	M	Athetoid, quadraplegic	Partial alphabet board & gestures	12/20/73	Resource special education room in public elementary school
S_5 (LS)	14	M	Athetoid, quadraplegic	Letter board, gestures	3/20/72	Resource special education room in public elementary school
S_6 (MS)	14	F	Spastic, quadraplegic, severe ATNR	Gestures with head, number board for math	11/14/73	Residential institution/hospital school for mentally retarded children
S_7 (TH)	12	M	Primarily athetoid, some spasticity, quadraplegic	Letter board, gestures, some communication through limited vocalization	3/15/73	Self-contained special education classroom in public elementary school
S_8 (DW)	12	M	Spastic, quadraplegic, hyperflexia in upper and lower extremities	Communication through gestures, some gross vocalization	3/15/73	Self-contained special education classroom in public elementary school
S_9 (MM)	17	F	Athetoid, quadraplegic ATNR	Language board, some intelligible speech, able to use masked typewriter with difficulty	1/5/74	Residential Hospital School

*None of the children were able to effectively use guarded keyboards.

TABLE 2. Description of Educational Environments

Subject	Type of Educational Environment	Classroom Description	Type of Educational Program in Classroom	Supportive Services
S_{CR}	Public Elementary School	Self-contained Special Ed Classroom	Multi-handicapped	Teacher Aide Occupational Therapist Physical Therapist Speech Therapist
S_{KS}	Hospital School	Self-contained Special Ed Classroom	Educably mentally handicapped + regular education for orthopedically handicapped	Teacher Aide Occupational Therapist Physical Therapist Speech Therapist
S_{DC}	Public High School	Resource Room	Regular education for orthopedically handicapped	Teacher Aide Occupational Therapist Physical Therapist Speech Therapist Homebound Teacher
S_{CC}	Public Elementary School	Self-contained Special Ed Classroom	Regular education for orthopedically handicapped	Teacher Aide Physical Therapist Speech Therapist
S_{LS}	Public Junior High School	Self-contained resource room	Regular education for orthopedically handicapped + learning disabled	Occupational Therapist Physical Therapist Speech Therapist
S_{TH}	Public Elementary School	Self-contained Special Ed Classroom	Multi-handicapped	Teacher Aide Occupational Therapist Physical Therapist Speech Therapist
S_{MM}	Hospital School	Self-contained Special Ed Classroom	Regular education for orthpedically handicapped	Teacher Aide Occupational Therapist Physical Therapist Speech Therapist

activities. For these reasons, a systematic teacher feedback system was developed to enhance the exchange of information between the teachers and the research group. Components of this system included formal questionnaires, classroom activity forms, periodic tracking questionnaires, taped (cassette) feedback, observational visits, and weekly phone calls.

2. Standardized Achievement Tests

The students who participated in the evaluation of the aid were administered a series of neurological test batteries. These tests were administered for the research group by the staff of the Department of Neurophysiology and Rehabilitation, University of Wisconsin Hospitals, under the direction of Dr. Charles Matthews. The purpose of these assessments was to provide comparative results for teacher-constructed tests and academic assessment measures which were under development by the research group. The test battery consisted of: Peabody Picture Vocabulary Test, Raven Progressive Matrices, Knox Cube Test, Columbia Mental Maturity Scale, Peabody Individual Achievement Test, and Boston Speech Sounds Picture Test.

3. Parent Contact and Questionnaire

Members of the research group kept in periodic contact with parents of children involved in the evaluation program. The methods employed for parental contact were phone calls, correspondence, home visits, and a questionnaire. The purpose of these formats was to elicit parental reaction to their child's use of the aid and to physical aspects of the aid. Most of the formats utilized were kept informal, with the exception of a more formal parent questionnaire which was designed to obtain specific parental reactions to their child's use of the aid.

4. Independent Evaluation - The Autocom at Kennedy Memorial Hospital

During the Trace Center evaluation period, an Autocom communication system was sent to Kennedy Memorial Hospital following the request of Robert Mann and coordinated by G. Dalympe (Acting Director, Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology). This Autocom was placed at Kennedy Memorial in order to have the aid independently evaluated in an educational environment other than those directly involved in the study and to establish a cooperative research effort with the Massachusetts Institute of Technology.

As this evaluation was not part of the formal evaluation conducted by the Cerebral Palsy Communication Group, and is still in progress, specific results are not discussed, although results were included in this report.

IV. RESULTS AND DISCUSSION

Since much of the data base is qualitative/evaluative information which was condensed from questionnaires, interviews, etc., and often relates to more than one of the objective areas of the evaluation, the results will be presented and discussed in their relation to the objectives of the study, which were

1) to study effect of aids on acquisition of math, language and spelling skills

2) to compare the portable and stationary aids

3) to study effect of aids on adjustment and interaction

4) to examine integration of aids into classroom and curricula

5) to obtain information for future aids development

A. EFFECT ON ACQUISITION OF MATH LANGUAGE AND SPELLING SKILLS

This area of exploration consisted of two separate but interrelated efforts.

1) The securing of quantitative information on changes in the rate of acquisition of certain skills

2) The exploration through qualitative evaluation procedures of the why or how of these rate changes.

The first part of this area - the securing of quantitative rate information on skill acquisition - was carried out in connection with the preparations for the Comprehensive Evaluation Program which was to follow. The evaluation program reported here was used to extend some procedures from a previous NSF project and to pilot test new procedures for use in the Comprehensive Evaluation Program. It was originally believed that sufficient quantitative information could be secured in this program to produce a preliminary publication on rate changes in skill acquisition. Collecting the quantitative information necessary from non-vocal severely multiply handicapped children in the diverse and remote education situations used in this program,however, proved to be beyond a program of this size. Although this type of quantitative information can be collected, this program found that limitations and constraints must be placed on the program implementation strategies and field placements, in order to secure sufficiently detailed information with this type of children. Because of the preestablished population of this study, these restrictions could not be implemented in this study. They were however delineated for use as guidelines in the subsequent comprehensive evaluation whose specific purpose was to gather quantitative rate information. A discussion of these constraints and limitations is contained in a latter section titled "Evaluation Implementation Problems and Guidelines for Future Programs".

Good information was obtained however on the "how" and "why" as well as the "why not" with regard to the aids facilitation of the educational process and skill acquisition. Table 3 provides a summary of the areas where the aid was cited as being a facilitator of the educational process for non-vocal, physically handicapped children.

The information on educational facilitation by the aid was centered around four areas: the amount of active participation on the part of the child, the amount and accuracy of the assessment and program progress information obtainable by the teachers, the amount of one-to-one time needed by the child and the child's ability to interact and participate in class group activities.

Active Participation

The first area of facilitation dealt with an increased ability for the children to actively rather than passively participate in the educational process. This was reportedly due primarily to the fact that the aid could be used by the child without the direct assistance of a second person. For many of the children this was the first time they had been able to "do" something completely independently. This generated an increased motivation to learn and to do a good job. Some of the children became compulsive about cleaning up small errors even in conversational communication in an effort to produce sentences they could be proud of.

In addition to the emotional or self image aspects, the child's ability to directly work and practice his lessons was seen as providing important feedback and active participation important to learning. In math, it provided some of the children with their first ability to manipulate the math elements. In fact math was reported as one of the areas most facilitated by use of the aid.

The principal feature cited in regard to the increased independent activity was the TV display which provided the children with a means for independent work. Their independence however was limited by the size of the TV display. The TV display, which did provide a very visible correctable display, held only 512 characters (approx. 1/4 typewritten page) on its screen. As a result some of the faster children were limited in their independence by their need to have someone copy the material off of the screen

Table

AREAS OF EDUCATION FACILITATION FROM USE OF INDEPENDENT COMMUNICATION AIDS

ITEM	FEATURES/CAPABILITIES OF THE AID INVOLVED	LIMITATIONS CAUSED BY AID
ACTIVE PARTICIPATION		
- ABILITY TO "DO" SOMETHING NOT HAVE IT DONE	- READOUT/PRINTOUT	ONLY HARD COPY WAS STRIP PRINTER ON PORTABLE AID, TV PROVIDED CORRECTABILITY BUT HAD TO BE COPIED OFF WHEN FULL (NO PRINTED PAGE COPY)
- ABILITY TO DO INDEPENDENT WORK AND HOMEWORK	- ABILITY TO MOVE AROUND ON "PAGE" NEEDED TO DO MATH; AVAILABLE WITH TV DISPLAY	
- INCREASED MOTIVATION - ABILITY TO PRACTICE LESSONS - ABILITY TO DO MATH MANIPULATIONS		
ACCURATE ASSESSMENT AND TRACKING OF PROGRESS		
- LESS INTERPRETATION - NO UNCONSCIOUS CUEING OF CORRECT ANSWER - LESS PRESSURE DUE TO IMPATIENCE OF TESTER - SEPARATION OF PHYSICAL AND COGNITIVE MISTAKES - SEPARATION OF PRODUCTION AND COMPREHENSION MISTAKES	- READOUT/PRINTOUT - CORRECTABILITY - VERY important here	- NO CORRECTABILITY ON PORTABLE VERSION EXCEPT WHEN USED WITH TV DISPLAY
INCREASED PRODUCTIVE TIME		
- LESS PASSIVE OBSERVATION	- READOUT/PRINTOUT	- NEED TO UNHOOK TRANSPORT AND RECONNECT TV, CHARACTER GENERATOR AND AID (AWKWARD, BOTHERSOME)
- LESS ONE-TO-ONE TIME	- CORRECTABILITY - NECESSARY FOR INDEPENDENT WORK OTHERWISE 2nd PERSON STILL NEEDED TO MAKE CORRECTIONS	
- MORE ACTIVE/PRODUCTIVE TIME (LESS PASSIVE OBSERVATION) - ABILITY TO ASSIGN HOMEWORK		- PORTABLE AID NOT CORRECTABLE (EXCEPT WITH TV) REDUCES LEARNING POTENTIAL AND INCREASES FRUSTRATION WHEN NOT HOOKED TO CORRECTABLE TV DISPLAY
	- PORTABILITY ALLOWS USE AND LEARNING IN MANY ENVIRONMENTS.	

(continued)

Figure 9 (cont'd)

INCREASED INTERACTION		
- ABILITY TO COMMUNICATE TO PEOPLE ON THE RUN	- PORTABILITY - SELF-CONTAINED PRINTOUT FOR MESSAGES, NOTES ETC.	- PRINTOUT NOT CORRECTABLE - PRINTOUT NOT HIGHLY VISIBLE TO CHILD OR OTHERS - NEED TO WAIT TIL DONE TO SEE STRIP PRINTED OUTPUT
- ABILITY TO QUESTION - ABILITY TO PARTICIPATE IN GROUP DISCUSSION - LESS ONE-TO-ONE TIME		
OTHER		
- INCREASED VOCALIZATIONS	- AID AS BACKUP TO SPEECH TOOK PRESSURE OFF OF ATTEMPTS - INCREASED EXPERIENCE IN COMMUNICATING	

so they could erase it and continue. When given the choice between the TV with correctability but limited size and a typewritten output with no correctability but unlimited capacity (endless paper roll) both teachers and children chose the TV display however.

Accurate Assessment

The second area of facilitation centered around the ability of the teachers to accurately assess the capabilities of the children and track program progress. Because so much of the interaction with these children previously consisted of yes/no-20-questions types of interaction or direct interpretive communication using a manual letterboard, there was much room for inadvertent cueing or misinterpreted response. As a result most all of the teachers reported surprise at the results of evaluations conducted once the child had an independent response mode where his answers need not be interpreted and could not be cued. Generally the teachers reported that the students knew the material less well than previously believed. Although disheartening at first they found this ability to accurately assess and track to be among the most valuable assets of the aid to the program.

Several aspects of the aid were reported to contribute to the increased ability to accurately assess the children's abilities and problems. First, as mentioned earlier, was the elimination of interpretation and inadvertent cueing on the part of the tester. Secondly, the children were able to work at their own pace without causing frustration or cumulative anxiousness on the part of a tester. Thirdly, and most importantly, the children were able to see and correct their own mistakes. When working on a manual letterboard with an interpreter it is very difficult for the individual to direct the interpreter back to clean up an erroneous letter or misspelled word occurring in the past message. Yet this is very important to separate 3 types of errors that were identified in this program as being made by these children.

1) Physical error - due to activation of wrong "key" or square on aid

2) Production error - wrong word or tense is produced but child can recognize error when looking at word or sentence

3) Comprehension error - child makes an error which he does not recognize as such.

An example of the importance of correction in assessing skills and problems can be seen in the following example produced by an advanced letterboard user (age 17, approx. 9 years on letter/word board). The user was working on a correctable TV screen while a non-correcting strip printer recorded all of the substeps to forming her message. Her final corrected message read:

"THANKS FOR COMING"

This is a perfectly correct sentence. The strip printer however showed the following:

"PLEASE THANKS TO COFOR COMEDING"

Originally she chose a wrong but similar word which she then corrected. This was followed by a similar corrected mistake with the word "To" for "For". Finally a wrong form, which again was recognized and corrected. Without the ability to make corrections, her utterance may have looked like:

"PLEASE THANKS TO COMED"

or

"PLEASE THANKS TO COFOR COMED".

If she were working through an interpreter the confusing message may or may not have gotten through at all but surely would not have reflected either her abilities or problems.

It was data such as this that pointed up one of the most serious deficiencies of the aid under evaluation. Although it did have a correctable TV display, the aid itself (the portable version) was not correctable. This tended to limit the effectiveness of the portable aid as a portable aid (where it was not connected to the TV) especially for the students with less well developed language skills.

Productive Time

The third area of benefit was increased productive time on the part of the children. The benefits here were cited as being centered around a decrease in the amount of one-to-one instruction/interaction needed in the classroom, and the ability to assign independent work and homework to the children.

The aspects of the aids which allowed this were the printout or readout capability of the aids and the correctability of the display. Previous studies had shown that non-correcting output forms did not free the teacher since she would be repeatedly called upon to help correct mistakes etc. A shortcoming of the aids here again was the limited amount of information which could be held on the screen and the fact that someone had to copy the information which could be held on the screen and the fact that someone had to copy the information from the screen when it was full or the child was done. Although the screen size was sufficiently large to cover the needs of the young children, it was small for the advancing users.

Interaction

Increased interaction overall was the fourth area described by the field centers. Although this was reported more from the users of the portable aids it was also reported for some of the stationary aid users. Many of the lower language level children, however, were not sufficiently competent with the aid to use it for general interaction and relied on other means (gesture, etc.) for communication, using the aid more for academic activities. For those with advanced language abilities, the aid was used for questioning, writing notes and letters, and for conversation. In one to one conversation however, one boy would turn his aid off and use it as a manual letterboard because he found this quicker when he had someone available to go one-on-one.

Again here, the lack of correctable output and good visible feedback to the child were cited as shortcomings to the aid's use for interaction. Also cited was the inability of the message receiver to see the message until it was completed and ejected from the side of the aid.

Summary

Overall, teachers reported that the aid's greatest effects on the students' skill progress were providing the opportunity to complete tasks independently, the elimination of costly hours of one-to-one instruction, ahd the opportunity for students to see and correct their work.

B. COMPARISON OF STATIONARY AND PORTABLE AIDS

Since the portable version of the aid could also be used to control any of the output forms of the stationary version, this evaluation comparison was aimed at determining the advantages of the portable, word printing version over the stationary aid. Table 4 provides a summary of the differences between the aids. The major points of comparison between the aids are

1) Speed

2) Use with pre-spelling children

3) Increased interaction due to portability

Acceleration Factor Study

To secure information on relative effectiveness of the wordmaster feature in accelerating communication, the thermal strip printer tape was collected from each of the three children using the portable aids. This cumulative output was then transcribed and "spoken" word counts performed on the transcription. Table 5 provides a summary of the word frequency tabulations. The words found in the wordmaster of the Autocom (marked with an #) accounted for 1670 of the 3892 words tabulated or approximately 43%. The maximum that could have been achieved with 64 words

TABLE 4

FEATURES/ABILITIES OF BOTH PORTABLE AND STATIONARY AIDS	FEATURES/ABILITIES OF PORTABLE AIDS ONLY
- INDEPENDENT COMMUNICATION AID - STATIONARY OUTPUT FORM - CORRECTABLE)) - HIGHLY VISIBLE)TV DISPLAY) - "PAGE" FORMAT/SIZE)	- WORD/PHRASE PRINTING ABILITY - SPEED - USE WITH PRE-SPELLING CHILDREN - PORTABILITY - INCREASED INTERACTION - INCREASED COMMUNICATION CAPABILITY

Table 5

WORD FREQUENCY LIST[1]

BY FREQUENCY

WORDLIST II MARKED

Words which appeared more than once in the total sample of 3892 words are listed in the order of frequency with which they occurred.

	I	248		#	come	19			day	10
#	is	248		##	hurt	19			Friday	10
#	to	103			Mr. Caswell	18			they	10
#	and	97		##	know	17		##	tomorrow	10
#	the	83		#	think	17			don't	9
#	it	82		#	want	17			Madison	9
#	you	57		##	love	16			portable	8
	a	52			this	16			red	8
#	I'm	49		#	will	16			talk	8
#	me	40		##	would	16		##	thanks	8
#	my	40		#	give	15		##	today	8
#	in	38			going	15		##	when	8
#	have	37			mom	15		##	where	8
#	go	35			we	15			your	8
##	good	35			of	13		##	feel	7
#	are	31			at	12			Gregg	7
#	see	30			Dad	12			had	7
#	like	29		##	eat	12			he	7
#	for	28		##	get	12			home	7
#	on	28			got	12			hot	7
#	not	26			Auto-Com	11			Jill	7
	am	25		##	bathroom	11		##	make	7
#	now	25			be	11			man	7
#	that	25			camp	11			movie	7
#	do	24			dear	11			ok	7
##	because	23		##	friend	11			people	7
#	can	22			Jack	11			school	7
#	how	22		##	play	11			all	6
##	what	22		##	some	11			back	6
#	with	22		##	take	11			board	6
	hi	21			went	11	2113		bring	6
##	please	21		##	about	10	54%		children	6
##	look	20	1668		CPCG	10			daughter	6
			43%							

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

---

[1] It should be noted that words which were misspelled were included in the word frequency count, if it could be determined that the child understood correct use of the word by looking at the context in which he used the word.

Debbi	6
fun	6
girl	6
happy birthday	6
having	6
hope	6
independent	6
life	6
our	6
parents	6
picture	6
she	6
TV	6
watched	6
year	6
around	5
ate	5
bar	5
beautiful	5
communicate	5
counselor	5
dorm	5
from	5
handicapped	5
Harold	5
Lydell	5
move	5
nut	5
## repeat	5
sometimes	5
## sorry	5
## stop	5
tape	5
very	5
before	4
building	4
bingo	4
boy	4
but	4
by	4
Craig	4
can't	4
did	4
## every	4
Gompers	4
guess	4
hate	4
him	4
if	4
mean	4
miss	4
## more	4
out	4
saw	4
Sunday	4
Wendt	4
wheelchair	4
## why	4
wish	4
Wordmaster	4
writing	4
act	3
algebra	3
aware	3
cabin	3
classes	3
close	3
could	3
Daddy	3
different	3
director	3
doctor	3
dog	3
doing	3
exam	3
everyone	3
everywhere	3
getting	3
glad	3
good	3
group	3
heel	3
here	3
house	3
lake	3
legs	3
letter	3
mad	3
mail	3
many	3
mark	3
marry	3
may	3
maybe	3
much	3
name	3
need	3
no	3
old	3
outside	3
remember	3
rest	3
sew	3
show	3
sick	3
something	3
try	3
until	3
used	3
well	3
alot	2
ask	2
child	2
Creer	2
CP	2
dumb	2
end	2
expect	2
fair	2
fast	2
father	2
film	2
find	2
first	2
fish	2
free	2
graduate	2
happen	2
hard	2
higher	2
home ec	2
ice	2
it's	2
last	2
little	2
listened	2
lunches	2
midnight	2
morning	2
mostly	2
mother	2
newspaper	2
next	2
night	2
note	2
one	2
pat	2
pig	2
place	2

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

pop	2
pot	2
put	2
radio	2
received	2
respond	2
sack	2
said	2
sing	2
so	2
soft	2
speech	2
steak	2
store	2
sun	2
swimming	2
table	2
tell	2
there	2
together	2
too	2
ugly	2
use	2
while	2
without	2

from this wordcount would have been 54%. Thus it can be seen that the overall speed of communication can be approximately doubled with a moderate size wordprinting capability (about 75 words).

An interesting observation from these results is that although a wordprinting aid can increase the communication time for a given word by 6 - 8 times, the overall average increase in communication is only about twice (for a moderate sized vocabulary). Even a very large vocabulary would only yield a speed increase factor of 3 or perhaps 4 unless the vocabulary were chosen to provide most of the words on a given topic (Table 6). A speed increase of even 2 however can be significant socially when communicating and in terms of independent work. Simply slowing one's speech to half rate can cause a definite increase in the tension or anxiety level of your listeners.

Since phrases and select words can be added to this basic set (overall word capacity of aids used in evaluation was approximately 200) common phrases could be added to facilitate communication in conversational situations or situations calling for stereotypic responses. In these cases the speed of communication could be increased much more (3 to 8 or 16 times for a given message). Since the children in this study were only beginning to use extended capabilities of the word printing feature, and had not yet implemented phrase printing, no data was obtainable directly on this aspect.

The exact effect on the speed of communication therefore can vary widely and is very dependent on the context of the situation and the context of the message. The importance of the speed was also found to vary from very important in group discussions to moderately important in independent work situations.

Use With Pre-spelling Child

In order to obtain initial information on the use of the portable aid with pre-spelling children, one of the portable aids was placed with a child who had not previously used a letter/word board to communicate. Since only one aid was available, results in this area are limited. Examination of the output of this child (Table 7) however reveal that the presence of pre-spelled, commonly used words on his aid did assist him in constructing sentences which were interpretable by his teacher. This particular child was quite bright and rapidly began using long sentences such as those in Table 7. Because of this he was forced to go to a spelling mode since only a very large vocabulary would have had the diversity he exhibited in his communication. We were therefore not able to explore the use of the portable aid as a wordboard-only system for prespelling or pre-reading children (using pictures as cues to words). Studies are however continuing in this area under subsequent funding.

Interaction Study

The increase in interaction due to portability turned out to be

Table 6

Percentage of Words Not Spelled to Yield Given Speed Increase

Figures based upon average word length of five letters plus space.

SPEED INCREASE FACTOR	% OF WORDS SPELLED	% OF WORDS NOT SPELLED
X2	40%	60%
X3	20%	80%
X4	10%	90%
X5	2%	98%
X6	0%	100%

Figures based upon average word length of 7 letters plus space.

SPEED INCREASE FACTOR	% OF WORDS SPELLED	% OF WORDS NOT SPELLED
X2	43%	57%
X3	24%	76%
X4	14%	86%
X5	9%	91%
X6	5%	95%
X7	2%	98%
X8	0%	100%

TABLE 7

Samples of S_{CC} Output -
With Teacher's Interpretation

Wordmaster words are underlined

Stimulus: "What did you do last night?"
I com and aet arie whoch NT.
Teacher: I come home and ate and watched TV.

Stimulus: "What did you do last night?
I eat stad and whot the flid of what qs.
Teacher: I ate steak and watched TV, "The Flight of the White Geese."

Stimulus: "What did you think of the new baby?"
Mr. Caswell is not look hem because eaey red.
Teacher: Mr. Caswell does not look like him because his eyes are red.

Stimulus: "How do you feel?"
I am hot and hot of head.
Teacher: He is saying he has a fever.

Stimulus: "Tell us about the weather."
It is suna and clod.
Teacher: It is sunny and cold.

Stimulus: "What do you think of Ford pardoning Nixon?"
Nixon is go nut.
Teacher: Nixon is going to go insane.

Stimulus: "How are you feeling today?"
I come home and eat whot TV bed 365 days nuts.
Teacher: I come home and eat and watch TV 365 days a year - nuts !!!

integrally related to the language level of the individual, the family/ home style, school setup and the daily routine of the students. Because of the many factors affecting interaction, no general comments or conclusions were found through the program. A good overview of some of these variables can be obtained from the following case study notes:

Subject CC was not reported to increase his interactions substantially after having received a portable version of the aid. This is probably due to the fact that he largely needed the TV display as feedback in constructing his messages and was not able to take full advantage of the portability. His communications were also quite difficult to interpret.

Subject LS was quite adept at using the stationary board. When he received the portable aid, switched over quickly and was able to use it very well as a portable aid. His daily routine however limited his access to the board since he was only occasionally in his wheelchair when at home, etc. He did make extensive use of it when at school and it was estimated that 50% of his use of the aid was for interaction.

Subject DC was also a proficient letterboard user before receiving the portable Autocom. In her case, however, the aid was almost always available for her use, at home, travelling, at school, at summer camp, etc. As a result she was able to significantly increase her interactions when she received the portable Autocom to replace her stationary model.

Summary

Overall the program showed that the extent of the benefits of a portable or word/phrase printing aid are very dependent on the application of it. In fact the specific benefits may be less related to the physical features than to the manner in which they are used or matched to the child's environment and communication skills. Thus the benefit of a portable aid may not be realized if it is inconvenient to carry or set up for the child, and the degree to which an individual can benefit from a word printing capability will depend heavily on the design of the vocabulary system for it and the specific skills or technqiues which are developed to facilitate communication using the vocabulary set/system. It is clear from the project that much more effort is needed in the area of application in order to complement the physical design activities and realize the full benefit of these aids.

C. EFFECT OF AIDS ON INTERACTION AND ADJUSTMENT

The objective here was to explore the effect of the aids on the children's self-identity motivation and relationships to others in his life. Although this is a very difficult area to assess, earlier programs identified it as one of the areas of significant effect for the aids. It was therefore included as a component of this program to explore the reasons for the effects and to determine if there were ways to facilitate these benefits through better designs of future aids.

Feedback from the evaluation program identified 8 areas that were facilitated by the aids which resulted in changes in the children's interactions and relations to those in their environments (Table 8).

The most fundamental of the effects was the effect on the children's self-image and motivation resulting from their ability to independently do something. For many of the children this was the first time they had ever been able to do something or produce something successfully by themselves. Teachers reported an increased motivation to learn. Part of this was attributed to the children's pride at now being able to show "their" work which resulted in diligent effort to do their best.

The ability to demonstrate to others his abilities and lack of mental retardation had positive effects on both the child and those in his environment. For some parents, the child's demonstrated abilities came as a surprise while for others it was a confirmation of long-held beliefs in their child. The effect on peers, siblings and relatives was also significant, and increased interaction with the children as a result of his newly demonstrated abilities was reported for all these groups. In addition changes were noted in the sibling and parent relationships in some of the families.

Emotional expression was cited, particularly by the parents of many of the children, as having been significantly enhanced by the aid. This included expressions of anger/frustration, personal feelings, the ability to express beliefs in writings and the expression of humor. An 8 year old child saying "I love you" for the first time to his/her parents can have a profound effect on the relationship between them.

The child's new-found ability (and tendency) for dissent was met with surprising enthusiasm by the teachers and others working with the children. The children themselves reported the joy or relief resulting from the ability to tell someone off - or swear - without being cut off as happens with a manual letter board. Teachers and parents reported "a new child" or "a deeper personality" as surfacing or becoming evident as a result of the children's increased ability to express themselves. This area was emphasized by teachers and parents as being a particularly important area and should be examined carefully in the development of more effective communication aids and vocabulary systems.

Teachers reported that the children who were proficient on their aid seemed to be more interested and inquisitive than previously. This was theorized to be related to both their increased ability to question ("What do Japanese do....") and their increased ability to talk about and share their experiences.

The aid has proved to be of vital importance at home for some of the students. While at home, the aids are used by the students to communicate with family members, to write letters and notes to friends, and to complete homework assignments. Prior to the Autocom, completion of any of the above required that some family member stop his activity and devote full attention to the child while he attempted to express his thoughts. This caused frustration for both the child and the

TABLE 8

Eight Areas Facilitated by the Aids which Resulted in Changes in Children's Interactions and Relations to those in their Environment.

- Ability to "do" independently
- Proof of Capabilities, Mental level to Others
- Emotional Expression
- Dissent
- Means to Communicate - yielding greater interest in Environment
- Reduction in Burden on Others
- Increased Communication Opportunity
- Ability to do certain things

family. In one instance, a student's mother would typically spend around 20 hours per weekend copying down messages or doing homework with her child's wordboard. Now that the Autocom has become part of this family, this mother has stated that she could never go back to spending hours of time tediously writing notes, and estimates that she now has about 75% more free time to attend to other family activities. By creating a more relaxed and less frustrated atmosphere, family relations have improved greatly, and the students have become active members in family activities and conversations. In looking at the development of new aids, the convenience associated with their use in the typical household should be given particular attention due to the large amount of time and personal interaction that occurs there.

The children themselves report increased opportunities to communicate as a result of not having to take up a person's time for the whole time it takes to assemble their message.

> "I can write my ideas down right away - before people didn't have patience to talk to me."

Often the children will prepare a message in advance or while someone else is talking or active doing something. In one-on-one conversations, the aid was not shown to be any more effective than the manual letter board. Except for one child (CC) whose pointings were so irregular that only the aid could figure them out sometimes, most of the children found it faster to communicate with another board or with the aid turned off when they were working in a one-to-one conversation where the other person had nothing to do. Occasionally however, the aid may get turned on if the child wasn't getting a chance to finish his thoughts or get his comments in. This area (CONVERSATION) is one of the most difficult areas since the aid cannot significantly increase the speed of communication (except for stereotypic responses) and because of the importance of rapid communication in the conversational or group situation. Of all the areas, this is probably the one which is most affected by their handicap and which is most important in the everyday interaction between these individuals and everyone else in the world. It is probably, therefore, the most important one to address in the development of newer aids aimed at advancing the overall well being and development of the child.

The last area deals with the ability to perform certain types of activities such as letter writing, daily notes to family and friends, play,homework and independent writing. The ability to write notes in privacy (on the strip printer) and have them sent unread was emphasized as being particularly important to one of the children. For another the ability to do artwork by printing characters on the TV screen provided him with his first ability to constructively play. For another it was the ability to do independent writing projects including an editorial for the Chicago Sun Times on abortion of the handicapped.

Overall, parents, teachers, and clinicians all emphasized the role of the aids in the area of social/emotional facilitation and encouraged any modification to enhance these capabilities in the children.

D. INTEGRATION INTO EXISTING CURRICULA AND CLASSROOM PROCEDURES

Information on the integration of the aids into educational procedures covered 4 areas

1) Utilization of the aids
2) Skills taught using the aid
3) Compatibility with materials
4) Compatibility with classroom setup and procedures

During the study it was found that while in the classroom the aids, particularly the stationary aids, were used more for academic/educational aids than as communication/interaction aids (Table 9). As much as 80% and an average of 64% of the children's work was done using the aids. This was primarily composed of independent work or in class work not associated with discussions (Table 10). The only two students who were able to use the aid significantly during discussion (20%) both had portable aids and were proficient word/letter board users.

Specific educational skills taught through the use of the aid varied with each student and were primarily dependent upon skills acquired or skills which teachers assumed were acquired by a student prior to receiving the aids. Overall, these skills included: arithmetic skills (from recognition of numbers to algebraic equations), sentence construction, spelling, acquisition of reading skills, vocabulary development, comprehension skills, computer programming, and self-expression (Table 11).

Academically, the aids were employed in tutorial and structured teaching, the completion of assignments and tests, classroom discussions, and, in one case, aiding limited verbal communication. Teachers commented that both the stationary and portable aids adapted well to existing curricula, and that fewer modifications of curriculum materials were required as compared to their previous modes of instruction (letterboards, gestures, etc.). Educational materials and programs which were successfully utilized in conjunction with both types of aids included: Distar, Fountain Valley Reading System, Sound Foundations, S.R.A. Reading Series and Ginn and Holt elementary arithmetic curricula. The major shortcoming of the aids was the inability to use preprinted or preprepared worksheets. One teacher got around this problem by preparing clear plastic worksheets which could be taped to the TV screen. The child could then fill in the answers. This was especially helpful in the area of math where it takes 17 steps to print a simple problem on a TV screen (or typewriter) (Fig 9a). In order for these types of aids to be truly effective in the educational environment, some form of correctable printer which can use preprinted or teacher prepared worksheets needs to be developed.

Other problems encountered dealt with advanced math symbols. The math problem arose as 2 of the students moved into areas requiring use of the square and square root symbols. In one case a square root was formed

Table 9
Description of Time Spent Using Autocom and Situations in Which it was Used for each Student

Subject	Amount of Time Used		Classwork Seatwork/Homework			Other Uses		Situations Where Not Used	Ability to use Autocom Independently vs. 1:1 Teacher/Student Contact	Educational Environment
	1a	1b	2a	2b	2c	3a	3b			
	Average Time Spent on A-C Before Taking a Break	Time Compared to Previous Method of Communication - Longer, Same or Shorter	Hrs/Day A-C Used	Approximate % of Classwork Completed with A-C	% of Time A-C Used for Classwork (vs. Other Use)	% of Time Spent for Other Uses Out of Total Time Used	Description of A-C's Use For Tasks Other Than Educational			
S_{CC} (portable)	1 hr	same amount	4	70%	90%	10%	-when not clear what student is trying to communicate -occasionally writes messages to entire class -artwork, makes designs & pictures w/ symbols	Group work (used in a multi-handicapped classroom & only one other child in the class could read)	Independently	Resource Special education room in public elementary school
S_{DC} (portable)	1-4 hrs	longer period	1½	80%	70%	30%	-takes it home weekends & spends about 4 hrs/day writing letters, messages, homework (1-2 letters/weekend) -plays tic-tac-toe on A-C -expresses opinions & makes comments	Short answers in which gestures can be used -not used during class period or group discussion, but for assignments & homework in study hall	Independently	Public High School resource special, education classroom
S_{KS}	1/3 hr	same amount	3/4	25%	100%	0%	None	-not advanced enough to use for sentences or social comments -not used in group situation	Uses it only with teacher	Residential Hospital School
S_{MG}	1/3 hr	longer period	2½	70%	95%	5%	-used very rarely when not clear what student is trying to communicate	-spelling is poor, so not able to use for social communication	Sometimes independently, sometimes needs teacher	Residential institution/hospital school for mentally retarded child
S_{LS} (portable)	1/3-½ hr	longer period	2	40%	50%	50%	-letter writing and conversation -when not sure what is trying to communicate -takes home occasionally	-group work -speech therapy -short answers where gestures can be used	Independently	Resource special education room in public elem school
S_{MM}	1 hr	longer period	1½	60%	95%	5%	-when not sure what is trying to communicate -takes it home occasionally for homework	-short answers in which gestures & oral communication can be used -group discussions	Independently	Residential hospital school
S_{TH}	3/4-1½ hrs	longer period	1-3/4	50%	95%	10%	-when not sure what is trying to communicate	-group work in which gestures & oral communication can be used	Independently	Self-contained special education classroom in public elem. school
S_{DW}	½ hr	longer period	1½	30%	100%	0%	None	-group work in which oral communication can be used -can't spell well enough to use A-C for anything other than classroom assignments	Sometimes independently, sometimes needs teacher	Self-contained special education classroom in public elem. school
S_{CR}	1/3-½ hr	same amount	½	50%	90%	10%	-occasionally when not clear what student is trying to communicate (gives a clue beginning letter) -speech therapy	-not used for other than classwork -group work or short answer requiring no written response. Other students in class can't read-easier & faster to use gestures in group	Sometimes independent, sometimes needs teacher	Public school day care program for young multi-handicapped children, housed in rural church facility
S=9		6 longer 3 same 0 shorter		$\bar{X}$ 53.8%	$\bar{X}$ 87.2%	$\bar{X}$ 13.3%	Other Uses -clarification of communication 7 -messages & conv. 3 -home use 3 -letter writing 2 -speech therapy 1 -art work 1	Not Used in -group work 9 -not able to use well enough for sentences messages or social communication 4 -short answers where gesturing or oral communication can be used 5	-independently -independently & teacher asst. -only with teacher asst.	

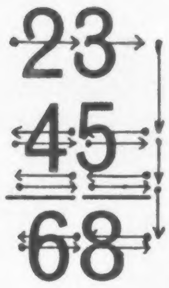
TABLE 10 Classroom Profile of Typical Daily Routines

Average Classroom Activities						Classwork Involving Use of the Autocom			
Hrs/Day 1:1 Instruction	Hrs/Day Group Instruction	Hrs/Day Physical Therapy	Hrs/Day Other Acty's	Average Hrs/Day Use of Autocom	Total Hrs Spent in Academic Instruc.	% of In-Class Academic Work	% of Class Discussion	% of Independent Work	Situations Where Autocom Was Used Most
2 hrs	2 hrs	½ hr	1½ hrs	4½ hrs	4 hrs	80%	20%	100%	general communication, printed copy, art work, letter writing, math, playing chess
4 hrs	2 hrs	½ hr	½ hr	4 hrs	6 hrs	40%	20%	100%	general communication, letter writing, art work, computer programming, tests, creative writing, playing tic-tac-toe
4 hrs	2 hrs	½ hr	1 hr	4 hrs	6 hrs	80%	5%	80%	supplement other attempts at communicating (e.g., gestures), "hard copy" work, art work, letter writing
1 hr	3 hrs	½ hr	1½ hrs	3 hrs	4 hrs	60%	5%	70%	math, general communication, "hard copy" work
½ hr	4 hrs	1 hr	1½ hrs	2½ hrs	4½ hrs	30%	5%	70%	to supplement limited verbal communication, all "hard copy" work, tests
½ hr	3½ hrs	½ hr	1 hr	2 hrs	4 hrs	70%	5%	80%	math, spelling and vocabulary development, supplement other attempts at communication, (e.g., gestures)

Table 11

Skills Taught Via the Autocom

1. arithmetic/math
    a) beginning number concepts, number labelling, and number recognition
    b) addition, subtraction, multiplication and division
    c) arithmetic equations
    d) initial algebra and geometry skills
2. reading and spelling
    a) letter recognition and labelling
    b) beginning spelling
    c) reading comprehension assessment
3. language and communication
    a) vocabulary development
    b) sentence construction
    c) language comprehension skills
    d) self-expression
4. computer programming



Small arrows depict
moves to get into
position to print
next character

FIGURE 9a

Illustration of steps needed to set up vertical math problem with the Auto-Com & T.V. output.

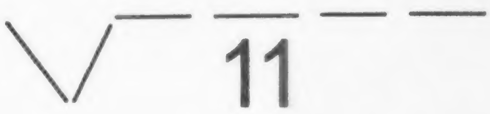


FIGURE 9b

$$3C''' = 3C^3$$

FIGURE 9c

Algebraic notation as written
on a T.V. screen with the Auto-Com

from a "V" followed by underlines above (Fig. 9b). Apostrophes were then used to denote the power of the numbers (Fig. 9c). Although these provided temporary solutions, the problem of special symbols needs to be explored further as these children move into more advanced work.

E. COMPATIBILITY WITH CLASSROOM LAYOUT AND CLASSROOM PROCEDURES

For independent work, the aids fit very nicely into the classroom and generally were set up in a carrel or on a table to the side. In several cases, teachers enhanced their students' independent work by employing cassette tape recorders in conjunction with the Autocom. Several students received instructions from taped lessons and performed their work on the Autocom, thus eliminating the need for a teacher aid to read task instructions. For one student, who had visual problems which interfered with the reading of text books and curriculum materials, lessons and instructions for skill tasks were also recorded on cassette tapes. The student would listen to the tape and then perform his work on the Autocom, employing a large screen television for a clear visual display.

The teachers also found that the aid now allowed them to assign homework and independent work, greatly increasing the benefit of their instructional time and allowing them to program for these children in a manner much more similar to the other children of their level.

The aids, however, did not lend themselves as well to classroom interaction. The stationary aids had to be set up to the side since it was awkward to set them up in the center and dangerous (especially to partially ambulatory children) to have power cords running across the floor. As a result the children tended to be separated from the class when positioned at the stationary aid. The portable aids did allow positioning anywhere in the room but had no convenient way for the teacher to see the child's message without walking back to read his strip tape. Repositioning the children can reduce these problems but future efforts at designing communication aids will want to take a closer look at these problems. First and foremost a communication aid should facilitate interaction.

F. CONSIDERATIONS FOR THE DESIGN OF FUTURE AIDS

The implications of the evaluation program results on the design of new aids have been discussed throughout. In summarizing them it is helpful to break them down into 2 categories

1) Design/Engineering/Technology Problems

2) Communication/Interaction Process Problems

The first category is characterized by the physical design of the aids and is usually constrained by existing technology and cost. Among the items or topics identified through this program were:

Visible Display - Although the TV display did provide a highly visible display for stationary use, the portable aids had no display other than the strip printer. A more visible display was requested both for the user's benefit and for the message receiver. The user often needs the display to assist himself in constructing his sentences. The message receiver can also often help speed up the communication process if he can follow along as the user is spelling out the message. The teachers and users did not want to lose the strip printer however to gain such a display.

Correctable Display - Correctability was also emphasized as being needed in the portable aid. For those with poor language or physical skills it was necessary to form intelligible messages. It also allowed for language development on a continual basis as well as allowing the children to put out messages that were representative of their capabilities and mental level.

More Vocabulary Flexibility - Teachers noted the limited vocabulary ($\approx$200 words) of the aids as well as the relative inflexibility. Approx. a third of the words (64) were pre-chosen and frozen on the aids they received. Moreover words could only be changed by sending cartridges back to the center for reprogramming. Future aids should be designed with the capability to handle larger vocabularies as well as the ability to alter the words in the aid on a day-to-day basis. Ideally it should be possible for the children themselves to do this from their aid. Such an ability would allow these users some of the flexibility and reversability in their communications that we exhibit in ours. It would also facilitate the use of these aids with very young children where words are initially introduced one by one and as they become meaningful in the children's lives.

More Functional Accessories - Accessories need to be designed which can allow these individuals to use more traditional materials like worksheets, forms etc. A good portable correctable printer which can accept regular paper sheets or pages is needed. Such an aid would be of immense benefit not only in the educational situation but in their independent activities and employment opportunities as well. If properly designed such an output form could be used with most any aid including simple low-cost non-printing aids.

Also needing further research are techniques for allowing these individuals to do mathematical operations with their aids. Problems were identified relative to irregular characters and difficulties in performing manipulations. Characters such as divide, square root, and the powers (squares,cubes,etc.) are not available on current output devices. In addition, it takes extensive work to move the cursor around on the screen to do long division problems or subtraction with borrows,etc.

Size Weight: Cost - Problems that continue to need better solutions are the size, weight and cost of these aids. Although the size of the aids used in this study was not a problem (they were made that size in order to be functional as a laptray) the weight and cost were. As the aids get heavier they become more cumbersome and bothersome. As a result they are not always kept with the child or mounted on the chair where he can use them. The cost currently is often difficult for parents to handle themselves and funding mechanisms do not yet exist for these aids.

In addition to these physical design problems, a need for much more research was identified in the area of identifying or developing the most efficient communication processes or procedures for use with or by individuals who must communicate in this way. Current techniques may provide independence but are still quite slow. Wordprinting capabilities increase the speed of communication but are limited in their effect by the size of their vocabulary. Perhaps there is a way to communicate which uses a subset of the English vocabulary (a subset which could be efficiently stored and accessed as a vocabulary in an aid) which could be used as a core vocabulary and allow communication on a wide variety of topics without having to do extensive spelling. A project at the Trace Center attempted to do this and failed about two years ago. But considering the importance of speed to the communication and interaction opportunities of these children additional efforts seem to be warranted in this area.

Evaluation Implementation Problems and Recommendations for Future Programs

As mentioned earlier, attempts to test run meaningful quantitative rate data collection procedures with the population in this study were unsuccessful. The following discussion summarizes problems that were encountered in this program as well as other potential problems identified. Suggestions are provided for trying to implement evaluation programs involving the collection of learning rate or other quantitative data on impact of the aids with non-vocal multiply handicapped children.

The principal problem areas identified in this study were:

1) Variability and Dropout/Return Children

2) Irregularity and Changes in Educational Programming

3) Evaluation Measures

4) Program Implementation

Children

One of the largest problems in developing a program to study the effect of (something) on the development rate of learning of severely multiply handicapped children is the extreme variability of the children. Physical, cognitive, family, support services, educational program, educational history, past experience, communication skills, social skills, health, vision, hearing, motivation and emotional maturity are only some of the many variables which must be considered and controlled for. These children are much more prone to problems in these and other areas and seem to be much more totally affected and affected for a long time by these problems than normal children. As a result it is not possible to pair children for control and it is common to lose data for extended periods of time due to complications in the children or their lives. The unpredictability of this latter problem is currently worsened by the very dynamic and frequent changes that are occurring in the children's lives as people try to comply with recent legislative mandates.

Educational Program

In addition to the child variables one also has to be prepared for the variations in the children's programs. Effective and defined programs for these children are only now beginning to be formulated. As a result, teachers are rapidly changing their educational programs as they try to find programs and approaches which are meaningful and effective with these children. This makes it extremely difficult to provide any organized approach to tracking their progress in specific areas. Since no instruments exist which can be used effectively with these children, they must be created or modified by the research program staff. With frequent program changes occurring, it is not possible to have effective tracking instruments ready unless close cooperation is maintained throughout this process. A close working relationship and an understanding by both the teachers and the researchers of the constraints imposed by the educational process and research design are critical to a successful program.

Even careful pre-arrangements, however, can run into problems where children change teachers or classrooms during the study. Since most of these studies will occur over more than a one-year period, this is not only possible but probable. In addition, the entire programming approach in which the child is enrolled may change as the schools move to better meet their educational mandates and priorities. An evaluation program must bear these realities in mind and if the design cannot be made simple enough to be able to accommodate these, then it should probably not be attempted.

Evaluation Measures

Because of the severe handicaps of the children, both physical and in terms of past educational experience, the rate of change in the beginning is likely to be very slow. As a result, the test instruments will have to be fairly sensitive. It is currently difficult to develop such tests since very little is known about the development of skills in the areas of language, mathematics and general cognitive functioning for these children who have little if any ability to express or use langauge or to interact or manipulate their environment. Preliminary efforts to develop effective measures for these children suggest that the order of acquisition of skills may differ from that which is measured in normal children. There is some indication that the children develop alternate strategies for answering questions and are successful at doing so for items which are beyond or based upon other items which they fail, but which need be considered necessary concepts for the items passed.

Formal tests, even adapted formal tests of general ability, prove to be of little benefit in the study. A series of six tests including the Peabody Picture Vocabulary Test, the Raven Progressive Matrices Test, the Knox Cube Test, the Columbia Mental Maturity Scale, the Peabody Individual Achievement Test, and the Boston Speech Sound Picture Test were given to each of the children on a pre and post basis. Results of these tests show little, if any, significant progress. More importantly, the variability of achievement even within subsections of each test demonstrate the variability of the performance due to artificial factors. A summary of the results of the testing are provided in Appendix A of this report. At the request of the tester, no further summarization is provided here.

Because of the lack of formal test materials for these children, either informal testing or adaptations to formal tests (which render them informal) appears to be the most appropriate way to proceed. The diversity of the children's skills and skill levels, however, will require that the children be carefully selected to be in approximately the same skill range. If not, then extensive periods of time and effort will be needed to develop the different tests over the very broad ranges that these children exhibit. The measures will also have to be made quite flexible in order to be able to accommodate wide fluctuations in the abilities of these in the same child over time. Since the children also appear to develop interesting strategies for correctly solving problems or answering questions while lacking a firm understanding of the basics involved, measures should include items which carefully cross-check skills for acquisition.

In addition to the content of problems involved in the design of effective measurement instruments, there are also significant implementation problems due to the severe communication and manipulation handicaps of the children. This is especially true for data being taken during the baseline period when the child has no independent means of clearly responding or imitating choices. The usual techniques of sequential presentation or multiple choice greatly limit the types of language and other skills which can be measured. They provide the child with the correct answer which must merely be identified rather than produced and they are terribly prone to inadvertent cuing, especially when even the child's yes and no may need to be interpreted by the tester due to his physical involvement. Many of the children have developed marvelous strategies for reading their testers and frequently show increases in physical control when working on difficult problems further masking their yes and no responses.

Program Implementation

Many problems arose or were more difficult to handle as a result of the manner in which the program was implemented. One of the most critical factors was the distance between the reserach group and the field evaluation centers. Whereas this facilitated the independent use of the aids and did not hamper the collection of qualitative information on the effectiveness of the aids, it posed severe problems in the collection of the quantitative data. This is especially true where classroom problems reduced the ability of the teacher or staff of the school to take the data themselves. The distance also caused delays in notification of particular problems which arose during the study.

A second situation which should be avoided is the changing of the project personnel which means contact with the schools. A rapport and feeling of continuity are critical to trying to maintain contact effectively with the teachers and to conducting research in an educational setting. In addition, the teachers themselves should be brought into the data collection design procedure and should be considered members of the research team implementing the program.

Because of the variability and severe handicaps of the children, this study should be designed to cover a fairly extensive time period. Of particular importance is the baseline period. Past records of the children's abilities and learning achievements are of little or no use as quantitative data. Often, the first thing that is discovered after providing the communication aid is that the children have not progressed nearly as far as was previously thought. As a result, a sufficiently long and very carefully tracked baseline period will be essential to any useful rate change study. This may, however, prove to be the most difficult part of the study once teachers are informed of an aid which could provide their children with an effective means to communicate and interact. It is very difficult or impossible to convince them that they should wait a year or two while you secure funding, develop the measuring instruments and conduct the baseline period before allowing their child to secure one of the aids.

Suggestions for Future Research Studies

The following suggestions for implementation of teacher evaluation studies designed to collect quantitative data on changes in rate of learning have been developed as a result of the evaluation program and the preliminary work on the preparation for the comprehensive evaluation program:

Close proximity of field centers to research center

in order to facilitate intercommunication with teachers and to back up collection of data by teachers, this problem arises (be sure to have pre-arranged clearance to do so)

Simple flexible design - which allows for dropout and return of subjects and which compares child chiefly to himself

Simple data collection - which can be implemented by research staff if need be and only includes collection of absolutely essential information by teacher and research staff

Selections of roughly equal children in order to greatly reduce the range of evaluation instruments which will need to be designed and developed

Long baseline period - which allows for dropout and return of subjects and which does not rely on past records of children for quantitative data

Avoid promising a placement date for the aid until all baseline data are in hand and confirmed

Appropriate length for study in order to ensure that moderately sensitive instruments will be able to effectively measure change. This same constraint applies to the baseline period

Time to design measurement instruments, so that all instruments can be completed and tested prior to the initiation of the baseline period

Teacher involvement from start involved in planning of the program so that researchers are aware of constraints in individual classrooms and so that teachers understand and accept the constraints of research

Teacher feedback - a strong, effective, meaningful tool for feedback of results of the study throughout the study. If pre-release of results may bias outcome for study, then provisions should be made in that regard. The teacher, however, must feel that s/he is part of the team for an evaluation program which has many potential problems as these have to succeed.

Summary and Conclusions

The overall results of the program indicate that independent communication aids can be of benefit to non-vocal, severely physically handicapped individuals. This conclusion is based upon qualitative evaluation information from teachers, parents, and in some cases handicapped individuals themselves. Three aspects of the educational process were found to be facilitated: accurate assessment, independent work and interaction. The features or capabilities cited as contributing most to the facilitation of accurate assessment and independent work were the correctability, the highly visible display and the ability of the aid to produce output without the need for assistance. The feature cited as contributing most to interaction was portability.

In addition to confirmation of the usefulness of this type of aid, several shortcomings were pointed out in the aids evaluated. Of principal concern were: lack of visible correctable display along with the printer on the portable aid, limitations on the word/phrase capabilities of the aid, and the inflexibility of the aids which limited the teachers' ability to adapt to the particular needs of their children.

The study did not achieve any significant quantitative results due to a) inappropriateness of formal tests and b) problems in implementing skill tracking procedures in remote classrooms. The variables involved in conducting such a quantitative study were discussed, however, along with suggestions for constraints and procedures to control for some of the problems in future studies. Careful examination of the implications of the recommendations, however, raises serious questions as to whether such an evaluation can be reasonably implemented or cost justifiable. In particular, five major factors contribute to this. First, the length of time needed to implement the study appears to be around 4 - 5 years given the time needed for evaluation instrument development, baseline and test period. Aids are changing so rapidly at the present time a postponement now could result in significant improvements in aids and their roles in the classroom. Secondly, due to the baseline period that would be needed (control groups are of dubious value with such variable and diverse children) it would be difficult and perhaps unethical to keep children from receiving aids so that baseline information could be taken. Third, many research designs, such as BXBXBX, would be difficult or impossible to implement for the same reason. Fourth, the constraints on data acquisition and analysis may be able to prove little more quantitatively than can be demonstrated qualitatively or is generally accepted without proof (e.g., that a child with means to communicate and write can advance educationally faster than if he could not communicate or write). Fifth, most of the measurement instruments needed to track the skill development of these children do not exist yet, and it would be cost prohibitive to develop them for a single study.

This is not to say that there is not a need for definitive quantitative research in this area. It is just questioned as to whether conclusive data can be collected on the change in rate of learning of certain academic and language skills in NVSPH children with the current knowledge of their learning and language process (and resultant measurement instruments). Further, a survey of professionals in the field leaves a question as to just how important this information would be. (See A Source Book, available through the Trace Research and Development Center).

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APPENDICES

Appendix A

Results of Formal Evaluation Measures

A. Results of Formal Psychological Testing

All of the students were administered a battery of neuropsychological tests at least twice during the 16 month program period. These tests were administered and are reported by Dr. Charles Matthews, Psychologist, University of Wisconsin Neurological and Rehabilitation Hospital.

Psychological Testing

Three of the five subjects for whom test-retest data are reported here have been seen on two previous occasions, and test score changes are based upon comparison of second with third testing. The remaining two subjects have been seen twice, and thus test score changes are based on first versus second testing. The average elapsed time between examinations on these five subjects is 16 months. Because of the severe speech and motor handicaps presented by these cerebral palsied children, only a limited test battery could be administered. An attempt was made to employ tests which required no expressive speech response or motor performance other than pointing or head modding. With several exceptions, detailed below in the descriptions of the individual tests, this requirement was met. The test battery was as follows:

Peabody Picture Vocabulary Test (PPVT)(1), a test of receptive vocabulary size developed by Dunn. The child is shown a series of pages on which 4 objects or actions are depicted, and points to the one which matches the word spoken by the examiner. If motor control is insufficient to make a pointing response, head nodding, blinking or some other signaling system can be employed.

Raven Progressive Matrices (2), a nonverbal test consisting of 60 designs from each of which a part has been removed. The child chooses the missing insert from an array of 6 or 8 given alternatives, using a pointing or other nonverbal response. The test is conventionally described as a measure of "perceptual reasoning."

Knox Cube Test (3), a test of immediate memory for a series of movements. The examiner taps 4 cubes in a predetermined order and asks the child to do likewise. The procedure is repeated with successive series of taps, increasing in length and complexity of sequence.

Columbia Mental Maturity Scale (4) The scale consists of 92 items, each consisting of a set of 3, 4, or 5 drawings printed on a 6 by 19 inch card. The child is required to identify the drawing that does not belong with the others, indicating his choice by pointing or nodding.

Peabody Individual Achievement Test (5), a wide range screening measure of achievement in the areas of mathematics, spelling, reading recognition, and reading comprehension. With the exception of the reading recognition subtest which requires an oral response, the child can respond to all other subtests given by pointing to one of a number of alternate answers. Raw scores (RS) are converted to age and grade level equivalents.

Boston Speech Sounds Picture Test (6) The child is shown a series of plates, each containing several paired pictures of like-sounding objects (e.g., cat-bat, rat-cat, hat-bat). Test items are presented with a tape recorder and the child points to the paired pictures which match the words spoken (point to "cat-hat").

Table I presents raw score, percentile, mental age, grade equivalents and IQ scores for each subject obtained on the two examination occasions previously described. The Table also includes for each of the test-retest change score pairs a notation as to whether in the judgment of the neuropsychologist who evaluated the children and interpreted the test findings (Charles G. Matthews) the change represented meaningful improvement (+), worsened performance (-), or no significant change (nc). (see Table I).

Table II represents in summary form the test-retest changes which were reported for each subject in Table I. The number of children who were given each of the tests is specified in the Table as is the number of children who were judged to show improvement, worsened performance, or no change from test to retest examination. (see Table II).

Inspection of Table II shows that of the total of 35 test score comparisons available on the five subjects, 15 were judged to reflect meaningful improvement, 5 to show worsened performance, and the remaining 15 as being essentially unchanged. The most consistent change scores in a positive direction were associated with the mathematics subtest of the Peabody Individual Achievement Test, on which four of the five subjects were judged to have made significant gains, and the fifth subject showed essentially similar performance in the two evaluations. Two of five subjects also made substantial gains on spelling, and two of four made significant advances in reading comprehension as measured by this same test. Two subjects were given the Boston Speech South Discrimination Test, both of whom showed what was

TABLE III

SUMMARY OF TEST-RETEST CHANGE SCORES ON FIVE CHILDREN

Test	N	N			%		
		+	-	NC	+	-	NC
Peabody Picture Vocabulary Test	5	1	0	4	20	0	80
Ravens Matrices	4	0	1	3	0	25	75
Knox Cube	5	1	2	2	20	40	40
Columbia Mental Maturity Scale	4	2	0	2	50	0	50
Peabody Individual Achievement Test							
Math	5	4	1	0	80	20	0
Spelling	5	2	0	3	40	0	60
Read. Comp.	4	2	1	1	50	25	25
Read. Recog.	1	1	0	0	100	0	0
Boston Speech Sound Discrim.	2	2	0	0	100	0	0

Total # Comparisons: All Tests, All S's: 35
N(+) 15, N(-) 5, N(NC) 15.

TABLE IX

TEST (I) - RETEST (II) - RETEST (III) RAW SCORE VALUES AND CLINICAL JUDGMENT OF CHANGE SCORES ON INDIVIDUAL S's

S#	1			2			3			4			5		
CA(I)	6-5			12-11			14-10			21-0			14		
Test-Retest Interval I to II	8			8			7								
(MO) - (II - III)	20			11			20			15			16		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
PPVT RS	47	59	60	75	88	94	113	115	113	109	116		92	97	
IQ	82	97	90nc	80	92+	94nc	115	114nc	107nc	98	106+		92	93nc	
MATRICES RS	15	18	15	14	19		28	28	28	30	31		19	22	
PERCENTILE	50	50-75+	10-25-	45	5-10+		50	50nc	D50nc	50-75	D75nc		5-10	10-25nc	
KNOX CUBES X	7.0	6.5	19.5	5.5	9.5	8	12	14	13	13	10.5		11	10	
[illegible]	5.5	5.5nc	8.5+	5.5	8.5+	6.5-	15.0	15.5+	715.5nc	15.5	10.5-11.5		12.5	9.5nc	
[illegible] RS	52	50	59	71	71	77	82	90	88	79			70	78	
MA	5-9	5-7	6-3	7-8	7-8	9-1+	10-9	15-5	13-1	9-8			7-6	9-3	
IQ	90	79-	77nc	59	56nc	D65+	77	100+	D94nc	69			D53	D67+	
WRAT MATH RS	11	10	15	24	26	38	44	45	49	58	50		34	42	
*GRADE	0.3	0.1-	1.1+	2.2	2.4nc	3.7+	4.9	5.3+	6.7+	9.2	7.0-		3.3	4.4+	
Spell RS	22	18	20	20	23	27	26	21	24	40	42		39	41	
Grade	1.8	1.4-	1.6nc	1.6	2.0+	2.5+	2.7	1.7-	2.2+	3.9	4.2nc		3.8	4.1nc	
Read. Comp. RS			B20	20	21	B26	26	22	24	41	33		24	34	
Grade			B2.0	2.0	2.1nc	B2.7+	2.7	2.2-	2.5nc	4.5	3.5		2.5	3.6+	
Read. Recog. RS				18	18	28	9	9							
Grade			1.3	1.3nc	2.8+	0.3	0.3nc								
Boston Speech RS				6	2+	1+			4	1			2	0+	
Change Scores		2+	2+		5+	6+		3+	2+		1+			4+	
		3-	1-		0-	1-		2-	6-		3-			0-	
		1nc	3nc		4nc	1nc		3	5nc		2nc			4nc	

+=meaningful improvement
-=poorer performance
nc=no significant change

judged to represent a significant improvement. As was commented upon in the first year evaluation report of the psychological data, the Knox Cube Test requires imitative motor response, and in both the first and present sample, the failure to demonstrate improved performance on this test (in the second and current sample only one of five subjects showed improved performance, two actually performed more poorly, and two showed no change) is believed to reflect the essential stability of the subjects' motor handicap and its continuing interference with ability to make an appropriate response.

It should be apparent from descriptions given of the motor and speech status of the children in the present project that conventional psychological intelligence and achievement tests, even when selected to minimize motor and expressive language demands, are inadequate to assess the efficacy of the Auto-Com.

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Appendix B

Selected Case Studies

Anecdotal Report

of S_{DC}

While Using the Auto-Monitoring Communication Board

This nineteen year-old female has been diagnosed as a cerebral palsied quadraplegic with athetoid involvement. Prior to this study, she used a letterboard for communication. Letters were painted onto the top of her wheelchair laptray and she pointed, letter by letter, to spell out her message. During the 73-74 school year she was enrolled in a high school which had classrooms for handicapped students, and moved from class to class during the day. Since receiving her Auto-Com in April of 1973, she has used the aid on a regular basis with one of her teachers. The time during which she used the Auto-Com was in a one-to-one situation with this teacher and for independent study and completion of assignments. At the time this study began she was already able to use the aid competently. The handpiece she uses was designed for her by her father and consists of an inverted V shaped piece of wood on top of a flat wooden slider covered on the bottom with felt. (see Appendix C).

Use of the Auto-Com

The Auto-Com allowed S_{DC} to be much more independent in her work. Her teacher feels that this has reduced the time she usually had to spend with S_{DC}.

> "Now I can give S_{DC} a project to do independently, and I can go work with another student or students, and then I can go back to S_{DC} and get almost immediate feedback from her, whereas before if I wanted information that day, I had to be with her all the time."

S_{DC} has successfully used the Auto-Com for a variety of skills, including writing letters to friends and doing her homework assignments. Her mother stated that "S_{DC} is much happier to be able to do something by herself." Previously someone had to be with S_{DC} constantly when she was working to interpret her responses and record them. She now works for periods of 3 to 4 hours at a time with very little assistance.

One feature of the aid which has been employed to S_{DC}'s advantage is the ability to correct one's work. Her teacher wrote that previously "when somebody was writing down things that S_{DC} was indicating, they were writing it down in a place where S_{DC} couldn't even read it, because generally the receiver was sitting opposite S_{DC}." Now, using the Auto-Com, S_{DC} can see her work as she does it and this has proved beneficial according to her teacher.

> "She can see something on the screen and she knows whether or not the spelling is right, and she can go back and correct it if it's wrong. Whereas before she was indicating letters and it was difficult for her to keep track of what she was doing. In general, because she can print it herself and she has time to go back and read and then correct it, I think it motivates her."

Her teacher believed that this had helped to improve the quality of her work.

The TV display of the Auto-Com also helped her teacher to better assess those areas where S_{DC} needed most work.

> "The Auto-Com shows S_{DC}'s work more clearly, fewer unconscious answers are given by S_{DC}'s teacher and parents (less coaching - which often comes with oral teaching and learning). Now S_{DC}'s deficits are shown more clearly."

The teacher also noted that "the Auto-Com is great for more accurate testing of spelling, independent reading and comprehension, word analysis, and sentence structure." Comparing her previous experiences the teacher wrote,

> "The Auto-Com helped me to discover where S_{DC} was really reading at independently. When I was using the letter board with S_{DC}, I always felt that I was indicating the answer to her. I always felt that she could tell by the expression on my face, or the way I would write it down or something that what she was saying was wrong. This way I feel that I'm getting an honest evaluation of what she can do."

The Auto-Com has proven helpful not only in language skills but also has been successfully employed by S_{DC} in her algebra course. S_{DC} acquired the computational skills involved in elementary mathematics and when the study began was enrolled in a high school algebra course. She used the aid for her homework assignments and took her tests with it. In this manner, she was able to progress through two thirds of the algebra text currently used by the local school system. She also passed a test in January which covered basic algebraic concepts and later successfully mastered quadratic equations. Her teacher believed she learned things in greater depth and with more thoroughness since she could write the problems out herself and do homework assignments using the Auto-Com.

Social communication was another area where the Auto-Com affected S_{DC}'s life. While it was still easier to get simple "yes" or "no" responses just by watching S_{DC}'s expression, her teacher stated that "if it's anything where she would have to give an answer in one or two words, the Auto-Com is best."

Her teacher also reflected that,

> "Time is such an important factor during the teaching day and the student is very much aware of this. Worrying about taking others' time makes communication more difficult in itself for the C.P. student. The Auto-Com offers more independence and there's a relaxed atmosphere for communication. In this way, the Auto-Com increases productivity for time spent using the aid."

In less demanding situations where there are no time constraints. S_{DC} has begun to express her thoughts and emotions more. Other people's reactions and responses to S_{DC} have been influenced by this and S_{DC} feels that people have become more responsive to her as a result of her ability to make independent comments. In relation to this her teacher has noted,

> "S_{DC} never disagreed with me before. Now that she has the Auto-Com, I see a whole new personality blooming, because she does disagree and has strong arguments against things. I talked with S_{DC} after I saw this trend developing and she claimed that it's hard to disagree with someone when you have to spell everything out letter by letter and they can tell that you're going to express disagreement."

Anecdotal Report
of S_{TH}
While using the Auto-Monitoring Communication Board

This student is a thirteen year old quadriplegic with athetoid cerebral palsy. He had no distinct speech and communicated in gestures and guttural noises prior to use of the Auto-Com. The school which he attended in 73-74 was an integrated facility and the majority of the students were physically handicapped. In his classroom, one teacher was responsible for a class of 14 handicapped children. S_{TH} was one of two children in the classroom who were using an Auto-Com system: S_{DW} was the other Auto-Com student. Classes were held from 8:45 a.m. until 2:00 p.m.

Use of the Auto-Com

He first received his Auto-Com March 15, 1973. At the time this study was initiated the student had already become fairly accurate in his operation of the aid. He used a plexiglass handpiece (see Appendix C) which could be slid over the surface of the Auto-Com. Initially he needed close supervision from his teacher but in November his teacher wrote, "Today S_{TH} did a good job on sentences and did it alone." He became able to work out assignments for himself and could work for fifteen minutes and longer without any assistance from his teacher. S_{TH} worked on new vocabulary by using the new words in sentences and was highly motivated by working on the Auto-Com. In response to a question, "Has your attitude toward yourself changed since you have received the Auto-Com?" S_{TH} responded, "Yes, I can show people what I can do. School is a lot more fun." S_{TH} now spends 1½ to 2 hours a day using the Auto-Com. His teacher responded that the Auto-Com enabled her to have "more time since S_{TH} can do more work on his own." Toward the end of the year his teacher responded that he did most of his school work on the Auto-Com.

Because he can express his basic needs most rapidly through gestures or noises, S_{TH} used the Auto-Com for social communication only infrequently. However, when gestures and noises aren't sufficient for S_{TH} to make himself understood, he uses the Auto-Com. His teacher wrote, "I can understand the boys, but when I can't understand them, S_{TH} uses the Auto-Com to explain it to me in written form." On another occasion she wrote about S_{TH}'s ability to communicate with her through speech. "Reading and speech have improved since using the Auto-Com. There was a fear that the Auto-Com would prevent further improvement in speech, but it has improved S_{TH}'s speech since receiving the Auto-Com."

The Auto-Com has also had an effect upon STH's language and communication development.

> "S_{TH} has improved 100% in writing complete sentences since the beginning of the year. He now has to write his spelling words in sentences and has to answer comprehension questions after reading in sentences. Complete sentences were never necessary before the Auto-Com so it was difficult at first to write in complete sentences. Since using the Auto-Com I have been able to look at parts of speech left out and work on these."

As has been the case with other students in the study, the Auto-Com has helped improve the quality of S_{TH}'s overall skill level. He is able to do more total work per hour using the Auto-Com and his teacher has seen an improvement in the thoroughness of his work.

Appendix C

Evaluation of the Autocom at
Kennedy Memorial Hospital,
Boston, Massachusetts

Case Study

Laura

Kennedy Memorial Hospital

Boston, Massachusetts

Laura is a ten year old female who has been seen by Kennedy Memorial Hospital for Children since October 1969. She has a diagnosis of cerebral quadriplegia secondary to natal difficulties manifested by severe motor problems involving upper and lower extremities. She is without speech and her movements are marked chorea-athetoid type spasticity. She cannot reach with either hand but rather throws one hand and manages to touch an object. No clear voluntary movements are possible. The exception was that she can touch objects with her nose. After a trial of physical therapy and a wide range of adaptive devices and training in occupational therapy the team decided that the most productive way for Laura to function would be through the use of a head pointer. She, therefore, works in the following manner: when in her wheelchair, she sits on her hands and stabilizes her feet so as to limit uncontrolled movements. Her head pointer is an aluminum one-quarter inch tube which extends six inches from adjustable leather head covering. Using this, she is able to point, past, paint and use a vertically positioned elevated electric typewriter with a guard. Although this has been the most efficient way for her to function in school and therapeutic situations, there have been definite limitations. Basically, it continues to be difficult to estimate accurately her level of functioning, to carry-out classroom instruction, and receive feedback from her.

Laura is a highly responsive and motivated child. She seeks both social and cognitive stimulation. Verbally, Laura shakes her head for yes-no. She verbalizes a few sounds but is only partially understood by her family.

She is presently enrolled in a day program at a school connected with the hospital. Her class is located in a small room and there are nine other children in it. At this time, she is not receiving any special therapies with the exception of autocom training and a group for perceptual training one time per week. Throughout Laura's involvement in the hospital and day school, she has received evaluations of both her physical, speech, reading, perceptual and cognitive skills. The following include these scores and others. Her responses were given through pointing with the head pointer. Included are only her most recent scores.

Visual Acuity
1/74: O.U. 20/30 O.D. 20/30 O.S. 20/30
Convergence 4 cm, 5 cm MPC; left eye 5 cm NPC slightly turns out. Pupils equal reacting to light. Test material used: Allen card; no mal 20/30.

Cognitive
1/73: Columbia Mental Maturity
Mental age: 8.1 years IQ 81

Reading
6/73: Peabody Individual Achievement Test
Arithmetic: 1.3 grade
Spelling: 1.2 grade

Hearing
10/73 Pure tone Screening (15 db - re 1969 Ansil): passed

Speech (receptive)
6/72: Peabody Form A 6. [illegible] years

Cognitive/Perception
1/74: Raven Colored Progressive Matrices: 5 %ile for 10 years
Definition: this test is for "a person's present capacity for intellectual activity irrespective of his acquired knowledge." It is a test of "mental development up to intellectual maturity." It tests a person's ability to "apprehend discrete items as a perceptual whole."

Laura is presently working on the autocom in her classroom.

Please see attached sheet "Progress Report -- Laura H."

Ann Bullock, OTR.
Occupational Therapy Dept.
Kennedy Memorial Hospital
30 Warren Street
Brighton, Mass. 02135

AUTO-COM PROGRESS REPORTS

February - June 1974

Laura used the Auto-Com daily in her classroom. The TV monitor was positioned at an angle that the teacher and classmates could see the screen (11 inches). All components of the Auto-Com were located on one table (24" x 48"). This was somewhat bulky for a small classroom but the teacher rearranged the other students' desks.

The following comments are my general observations of Laura throughout the spring. More definite and substantial information will be supplied in the teacher's report.

1) Laura's head and neck control improved. Her tolerance for use increased from approximately 20 minutes to 45 minutes. Speed and accuracy also improved which I feel was partly due to the increased neck control. See speed test comparison.

2) Laura's verbalizations increased. Progressively during the spring, Laura's teacher commented on this. Laura said the following to me: my name, the teacher's name, no, a clear yes, and a variety of other sounds. During this time, she was not receiving any form of speech or language therapy.

3) Papers that the rest of the class were using were easily adapted to the Auto-Com. Description and context will be included in teacher's report.

4) Laura exhibited a mild reversal problem while using the Auto-Com. This indicates that she has some mild visual perceptual difficulty. She occasionally reversed 2 numbers and letters. Previously, we have not been able to document this. I do not think that this problem is significant enough to interfere with her learning.

During the last week of school, the speed tests were repeated. The results are the following:

	1/74	6/74
C O D G A L B J N J V Q P E Z	2 Mins.	1 min.2 sec.
A T K W L O M G H I S	2 min.15 sec.	35 sec.
E T A I L N O S H R D L	2 min.	45 sec.
U C M F W X G P B V K Q Y Z	4 min.30 sec.	1 min.9 sec.

In the above testing, she made one mistake on the second testing of the last group and she independently corrected it. Also, during the last week, we made a videotape of Laura using the Auto-Com.

Laura learned more characters on the board while it was in the classroom.

1) Sp (space) on right side of the board
2) period at end of sentence
3) teacher's report will include more.

We usually left the hand slide on the side of the board. Independently, Laura began to push it over the CLR (clear) with her headpointer. She then sat back and relaxed while the hand slide magnet did the work of clearing the monitor.

The Auto-Com broke down approximately two times during the year. Each time, George Dalrymple of MIT repaired it. In general it was a very reliable machine. It withstood several moves without difficulty and many hours of use: 2 conferences at other locations and up and down from the O.T.department.

Future Plan for Coming Year

1) Laura will continue to attend the Kennedy Day School next year. She will therefore use the Auto-Com in the classroom setting with the same teacher.

2) The teacher and reading therapist are planning to have a joint reading group! OR A GROUP OF NON-VERBAL CHILDREN

Reports

1) Reading therapist is in the process of describing her program with Laura and the Auto-Com.

2) The teacher's progress note.

3) The occupational therapist will send a summary of re-evals from psychology and speech.

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CC: C.Daniel Geisler/Robert Mann/George Dalrymple

mfs

Appendix D

A Portable Non-Vocal Communication Prosthesis for the Severely Physically Handicapped-- The Portable Autocom/Wordmaster

A PORTABLE NON-VOCAL COMMUNICATION PROSTHESIS FOR THE SEVERELY PHYSICALLY HANDICAPPED
THE PORTABLE AUTO-COM/WORDMASTER

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ABSTRACT

The Auto-Monitoring Communication Board (Auto-Com) is a significant new communication aid for those physically handicapped persons who have had to rely on language boards for their output channel of communication. Designed especially for use by athetoid cerebral palsied children, the device requires only gross pointing skills to operate. Initial results of an evaluation program have been encouraging and indicate that any child now capable of using a language board should be able to achieve independent communication through use of the Auto-Com. The Auto-Com is also suitable for use by other types of physically handicapped persons having communication problems. Particular attention has been paid throughout the design toward making the device as compact, simple, portable and convenient as possibe. The aid is now in its final development and evaluation stages and is due to be released for production within a year.

The purpose of this paper is to describe the Auto-Monitoring Communication Board (Auto-Com) and the basic principles by which it operates. For clarity of presentation, the paper is divided into three sections. The first section describes the auto-monitoring principle upon which the Auto-Com is based. The problem of athetoid movement is presented and the operation and characteristics of the auto-monitoring system are explained. The second section presents the Auto-Com, a communication device utilizing the auto-monitoring technique. A description of the aid, its different forms, and the considerations that went into its design are presented. The final section will discuss the preliminary results of the evaluation programs being run on the aid.

I. THE AUTO-MONITORING TECHNIQUE

Introduction

The communication problems of the Cerebral Palsied child who lacks the nueromuscular control necessary to speak or to write legibly are very severe. For some of these people, a typewriter with a handguard (Figure 1) has offered an avenue to communication. But for many, even the typewriter is beyond their capabilities, leaving them with little means to record or share ideas, questions or feelings.

Those who have a gross pointing ability may learn to use a "language" or "communication" board (Figure 2). While this technique represents a great step and is invaluable under some circumstances, it is still slow, often ambiguous and frustrating for both the child using the board and those "speaking" with him. This slowness tends to discourage communication, in that even the making of a casual comment on the part of a language board user requires a directed effort on the part of some other persons for several minutes. Because the second person is often involved in some other activity, taking time out to help the child becomes a distraction from this activity and an inconvenience to some degree. The child usually perceives this and, not wanting to be more of a burden, tends to further decrease his attempt to communicate. This type of distraction is particularly disruptive in a classroom situation where the teacher cannot turn from the rest of the class whenever a non-vocal child has a question or comment.

As a result, board users tend to talk relatively little most of the time, limiting the majority of their communication to immediate needs or to times when they have the undivided attention of another person. Even at one very well staffed facility (staff-to-patient ratio of almost 1-to-1) the staff indicated to us that they tended to have fewer conversations with communication board users who were slower and less precise in their pointing skills than they did with those that could "talk" faster with their boards. The amount of work involved was given as the reason. This problem is even more acute when these speech-impaired cerebral palsied people must deal with strangers or those not as dedicated to helping them. Because the dependence on a second person has such a restricting influence on the communication of these individuals, and because of the central role communication normally plays in the life of a child, it is quite important that some means of independent communication by developed for them.

Past Approaches to the Problem

Work has already been done in this area and several different types of devices have been developed. The biggest class of these devices utilizes a scanning technique. In these devices, the alphabet is generally arranged in a rectangular array, approximately 7 by 7. The device steps an indicator or cursor across the columns until signalled by the child and then moves it down the column until the child signals again. The selected letter is then printed on a typewriter, strip printer or other output device. The signals by the child are made by activating a single switch especially designed to take advantage of some one movement over which he has control. Because the indicator must pause at each step long enough for the child to activate the switch, this scanning process is quite time consuming.

This is especially true if the child has athetoid movements or cannot make a discrete response quickly. This approach does have the advantage that it can be used by almost any child who is able to spell, no matter how severe his physical disability. But, for those who possess gross pointing abilities, this method does not take full advantage of their capabilities and is, for those children, unnecessarily slow.

Another technique which has been developed for the severely handicapped uses encoding techniques to provide a means of communication using a limited number of switches. These encoding systems utilize one or more switches which the person operates in a repetitive fashion to encode his output. The Morse Code, for example, might be used in such an encoding system. This approach works best with people who have small but quick and well controlled movements such as might be found in the breath control of a para- or quadraplegic. For people with cerebral palsy and other afflictions which render them weak or limit their coordination, these types of aids are very slow and often cannot be operated without many mistakes.

It was in trying to find an aid for those individuals whose movements were too sporadic or uncoordinated for the encoding systems and yet not restricted enough to resort to the scanning technique, that the auto-monitoring technique was discovered. The problem at hand was that of developing a communication aid for those individuals who have some limited gross motor pointing skills but who are unable to operate a keyboard of any kind, even with special modifications. A scheme whereby the user would directly select each output letter was deemed most appropriate for these individuals because of their ability to point and the inherent simplicity and speed of a direct selection technique. The problem was then one of finding a way to optimally utilize their limited pointing skills.

After many experiments, a solution was found to lie in the combination of a matrix of proximity switches located beneath a smooth surface and the use of a delayed activation mechanism. Using this technique, the operator need not push or pull any levers, buttons or switches. He need only slide a pointer into the vicinity of a switch and hold it near the switch for a short time (see Figure 3). In order for the system to respond, the particular switch involved must be closed continuously throughout the short, though adjustable, period of time. If the switch is opened before that period expires, the system resets, ignoring the switch closure. This feature means that switches only momentarily activated due to the passage of the pointer over them are ignored. Only when the pointer is kept within the sensitive area of a switch uninterruptedly for the set period of time, will the auto-monitoring system acknowledge the switch closure.

Thus the switch matrix is sensitive to lack of motion rather than to discrete motions as in normal switching arrangements. Pointing briefly to other switch locations as the user moves the pointer around over the surface will cause no false triggering. Nor will mistakes occur due to movements or momentary loss of control by the individual while trying to point to a given switch. If the operator loses control of his motion, the system just waits "patiently" until the operator regains his control. By adjusting the activation area of these proximity switches to the proper size, errors due to small tremors and inaccuracies of pointing were also almost entirely eliminated.

It should be noted that this delayed-action proximity-switching technique was modeled after the same process that a second person would use if he were to monitor a handicapped person's movements in trying to point to various letters painted on the surface of a board. Hence the term auto-monitoring.

Using this technique, it is possible to locate a large number of switches within an individual's range of motion without causing any problems due to accidental triggering of switches adjacent to the desired one. Moreover, because the proximity switches are located beneath the surface of the board, the operator need only slide the pointer around over the smooth surface of the board, never having to pick his hand up or support its weight in the air. The removal of the necessity to suspend his hand above the switching array and the removal of the vertical dimension the required movement patterns have greatly increased the hand control of the cerebral palsied individuals worked with. The combination of all of these features has allowed even very severely cerebral palsied children to use devices which utilize the auto-monitoring technique.

II. THE PORTABLE AUTO-COM

Criteria for the Final Development of the Auto-Com

Once the Auto-Monitoring technique was discovered, several communication aids were developed using the technique. These aids (which all have the generic name of "Auto-Com" for Auto-Monitoring Communication Board), were evaluated with 10 children in various educational settings in Wisconsin and Illinois. Based upon these evaluation programs, the following criteria were drawn up for the final design of the Auto-Com.

1. **Durability**. Since this device was designed to be used with children, durability was seen as a major criterion. Children, especially motor involved children, are extremely hard on the objects they handle. Moreover, failure of the device would mean that the person would lose his mode of communication until it was repaired. The device therefore had to be able to take bumps, spilled liquids, and other common accidents and still perform reliably.

2. **Simplicity of Operation**. Because this device is used with very young children, it had to be designed so that operation was simple and straight-forward. Teaching to a young child is hard enough without the confusion of teaching the operation of a machine.

3. **Simplicity of Setup**. Since the severely involved individuals must rely on others for much of their care, the communication aid must be simple to set-up so that it does not become an additional burden upon those caring for the person. Also, non-technical persons have an aversion to hooking things together, as they usually do not feel comfortable with wires, cables and rows of switches. Thus, every effort had to be made to keep the devices simple looking and easy to maintain.

4. **Feedback**. Since these aids would be used with young children just developing language, it is important that they have very good visual feedback of their output. Many of these children also had visual problems, and/or head movement problems that made it difficult to read printed copy in a typewriter, even when it is placed close to the child.

5. **Printed Copy**. For children, printed copy is necessary for evaluation of work, records or progress, and reflection on previous thoughts, as well as for motivational value of having the child produce work he can exhibit to teachers, parents and peers. For adults, printed copy is necessary for producing independent work, keeping records, writing letters, and a host of other activities related to self-development, social interchange, education, and employment.

6. **Correctability**. Since these individuals do not have the manipulative ability to be able to erase mistakes in the normal fashion, some method must be provided for correcting their mistakes. In an educational setting this is important, both so that the teacher can determine the accidental mistakes from the actual mistakes in understanding by the student, and for motivational reasons on the part of the student.

7. **Speed**. The device should be able to allow the person to communicate at his maximum potential speed. The speed should be adjustable so that the individual can easily operate the device on his off days as well as on his good days. If possible, the device should allow the person to communicate word-by-word or thought-by-thought, as in normal speech. Ideally it should allow him to communicate at about the same speed as normal speech.

8. **Applicability**. The device should be designed so that, with minimum modification, it can easily be applied to individuals with a large variety of specific manipulative problems. It should also be applicable to individuals over a wide range of age and educational background.

9. **Versatility**. The aid should be designed in a form that lends itself to easy modification to be able to fit the specific requirements of the user. It should be simple enough to be used by a very young child yet versatile enough that it could be easily set up to interface with computers and other machines as the child grows to adulthood.

10. **Reasonable Cost**. Almost any set of criteria could be met given enough money to develop and implement the solution. The aim here was to solve the problem with existing technology and materials, and to do it at a realistic price. The adopted goal is to provide a communication device at about the same cost as a set of orthodontic braces.

The Portable Auto-Com

With these criteria in mind, the final model of the Auto-Com was developed. The prototype of this new unit which is called the Portable Auto-Com, is pictured in Figure 4. This Portable Auto-Com is completely contained within a 20" x 24" x 1½" thick, lapboard which mounts directly on the arms of a wheelchair, using standard Everest & Jennings wheelchair mounts (Figure 5). The control circuitry has all been designed in ultra-low-power electronics, to enable the device to run off a rechargeable battery pack, which is also contained within the lapboard. A subminiature strip printer is also mounted insider the lapboard as is a Wordmaster system (optional) which gives the Auto-Com the abililty to print entire words, phrases and sentences as well as single letters. The entire aid is completely self-contained, and weighs only 13 lbs.

Durability. The top surface of the Auto-Com has a hard formica-like surface. The letters and words printed on the Auto-Com were actually printed inside the formica-like sheet while it was being manufactured. As a result, the Auto-Com has a smooth, unbroken surface which is nearly indestructable. Because of the smooth unbroken surface, the Auto-Com can be used as an ordinary laptray when not being used to communicate. The individual can eat, drink, work or play using the Auto-Com as a laptray without fear of damage from spilled liquids or rough or sharp objects. Because of this, the Auto-Com can always be available right in front of the individual, without ever being in his way.

Simplicity of Operation. Operation of the Auto-Com is so simple that very little instruction is needed to operate it. The operator simply tries to point to the letter or word he wants with the magnet and waits for a click sound. The various extra features or capabilities of the board are introduced gradually as the user becomes more familiar with the aid. But it is not necessary to know about any of these features to use the board. The children are therefore usually using the Auto-Com within 3 minutes of the time they are introduced to it.

Simplicity of Setup. There is actually no setup involved with the Auto-Com itself. It is completely self-contained and need only be placed on the wheelchair in the same manner as a laptray. Since it is battery operated, there are no cords or plugs to bother with and the aid can move with the child wherever he goes. Thus, he would always have his "voice", even while moving around. For some extremely involved children who are unable to grasp anything, it is sometimes necessary to assist them by strapping the handpiece on for them. However, for these individuals a wristpiece (Figure 6) can be used eliminating the need to take a handpiece on and off during the day.

Feedback, Printed Copy and Correctability. The self-contained strip printer is a highly portable output form is convenient for conversation and short messages. However, it will not fulfill the total communication needs of a user, nor does it provide good visual feedback of the child's output which is necessary for learning. For this reason, the Auto-Com has been designed to interface with various other output modes. To do this, the Auto-Com is equipped with a special output connector on one edge of the board. With this output the board can be hooked directly to a teletype, a CRT terminal, a television display, a computer, specially modified typewriters, and other devices. These various output forms each have their advantages and disadvantages. The proper output form for any given application would depend on the requirements of the application in terms of visual feedback, correctability, need for printed copy, portability and cost. For the classroom situation for instance, the television display has been shown to be the most effective. It provides excellent visual feedback of the child's work while providing 100% correctibility, the single most desired feature of the Auto-Coms on the part of the students. It provides a display of 512 to 1024 characters allowing the child to do independent work that would not be possible on smaller displays. It is silent and relatively light compared to the weight of typewriters. It costs less than most output forms except the teletype, which is both very large and fairly noisy. It does not, however, provide the child with printed copy. The feature can be added to the television display, but would approximately double its cost. More detailed descriptions of the various output forms and other devices which can be controlled by the Auto-Com are described later.

Speed. The speed of operation of the Auto-Com is completely dependent on the pointing skills of the user. The Auto-Monitoring system is adjustable to handle individuals with quick and relatively accurate pointing responses as well as those with quick but inaccurate pointing movements such as an athetoid cerebral palsied individual and the very slow movements of a weak or spastic individual. Since even the skill or control of a single individual may vary from day to day, the speed adjustment is located in a convenient but out of the way position on the bottom side of the board near the edge. To further increase the speed of communication, an accessory has been developed called the Wordmaster. This unit enables the Auto-Com user to print out full words, phrases or sentences by pointing to a single square. Words can therefore be printed on the top of the board along with the alphabet and accessed in the same way the letters of the alphabet are. This ability to print common words without spelling them out letter by letter can increase the speed of communication from 2 to 4 times.

Applicability. The Auto-Com mounts to wheelchairs using the standard Everest & Jennings wheelchair mounts. These systems were chosen because it can be readily modified to fit any wheelchair with little effort. Because the brackets are completely removeable, the Auto-Com can also be placed flat on tabletops or laid on the floor or bed for use by individuals when they are not in their wheelchair.

Although the Auto-Com was originally designed for use with a hand slider, the cursor magnet used to operate the Auto-Com can be used in many different ways depending on the physical abilities of the user. Headsticks, mouthsticks, wristbands and fingerpieces have all been used to control the Auto-Com simply by attaching a magnet to them. A wide variety of different shaped, sizes and forms of handpieces have also been used with the aid. For some individuals, a felt-bottomed handpiece has served to facilitate the sliding motion over the board. For these people the handpiece serves both to stabilize the individual's hand and to smooth and damp his motions. Other individuals are using the magnet mounted on a watchband, both for convenience and to eliminate problems due to irregular hand motion. Still others are using the magnet mounted on special finger splints. In some cases a single child may have a couple of different cursor systems (such as a wristband with a magnet in it and a standard slider handpiece), which he switches back and forth depending on his situation or surroundings.

Finally, as mentioned earlier, the activation delay time has been made variable to allow for different types and degrees of pointing control.

Versatility. A special effort was made in the development of the Auto-Com to allow the aid to take different forms so that it could be simple enough in one form to be used with very young children and yet sophisticated enough to fill the needs of that child as he grew through adolescence and into adulthood. One of the major features of the Auto-Com which provides this developmental versatility is the Wordmaster with its interchangeable memory cartridge.

Because of the wordmaster function, the Auto-Com could be introduced to children at a very early age. overlays which would cover up the standard letter/wordset can be easily constructed and taped down to the smooth surface of the Auto-Com. In this way the letters and words ordinarily displayed on the surface of the Auto Com could be changed to pictures, symbols, or symbols paired with words. The Wordmaster could then, be programmed to print the word represented by the picture or symbol whenever the child pointed to the symbol. Thus a pre-reading child would be able to construct sentences or thoughts by pointing to the appropriate picture or symbol and having the thought or sentence printed out displayed on a TV screen where a teacher or other person could read and respond to the message. As the child progressed the pictures/symbols could be replaced with words, still using overlays to provide the child with a simple and limited visual display. Because of the memory cartridge, which allows one to easily change the vocabulary of the Wordmaster, specialized wordsets could also be prepared specifically for a child. As the child's language developed, the wordsets could be altered and expanded. The alphabet could then be introduced as the child learned to spell and communicate with a more diversified vocabulary.

For the older individual the present Auto-Com/Wordmaster has the capability of storing up to 190 words, or an equivalent number of phrases or sentences. Moreover, 128 of these are in the snap-in memory cartridge. Extra cartridges could be obtained and programmed with vocabularies specific to certain situations or locations. Thus he could have separate vocabularies for use at school, at home, at play or when travelling.

Price. The actual retail cost for an Auto-Com is not presently known as it has not yet been released on the market. Its retail selling price, however, is currently estimated at $1,500 and up depending on the options selected. This price can be compared to the cost for a full set of orthodontic braces ($1,500) or to one year of public education ($2,800).1 Based upon results of an evaluation of the Auto-Com, however, an effective mode of communication means far more to these individuals than braces, or a year of education could ever mean to another child.

Optional Output Forms For Use With The Auto-Com

For basic conversation and portable communication, the built-in strip printer is the best option available with the Auto-Com. But for educational use and for learning, the strip printer provides almost no feedback to the child and is therefore unsuitable. It also does not provide printed copy in a form which is very useful except for conversation. For these reasons, other output forms have been developed for use with the Auto-Com.

Television Printout

The best output form for educational purposes and for general use is the television display (Figure 7). Using an alphanumeric character generator, the Auto-Com can print letters directly on the screen of an ordinary television in much the same way as the airline terminals print their arrival and departure times on television monitors in airports. This format provides a display which is both highly visable and correctable. Because the letters are proportional to screen size, a television set can be selected to produce characters of any size up to about ½ inch high. There are 512 character positions on the screen, thus allowing the person to write a fair amount on the screen, review it and correct all his mistakes, before having to vcall someone over to review it or copy it onto paper for permanent records. The few disadvantages of this output form are: (1) whereas it is mobile, it is not portabe, and must be plugged into the wall to operate, and (2) it does not produce hard copy. The cost for this type of output form is approximately $800.

Teletype

The teletype provides an inexpensive form of full-page printout but does not allow for correction or even backspace to cross out mistakes. It is also a large and noisy device, which limits its use in classrooms and eleminates the possibility of taking it back and forth between home and school or work. The price of a teletype printer is around $700.

Transfer

To eliminate the problem of hard copy with the television display, a system called Transfer has been developed, which will automatically cause the contents of the television screen to be printed out on a teletype or special typewriter when the command to "copy" is given from the surface of the Auto-Com. The cost of this Transfer system would be approximately $200-$300, plus the cost of the teletype.

Modified IBM Correcting Selectric Typewriter

A special modification is available which can enable the standard IBM Correcting Selectric Typewriter to be controlled electrically. This would allow the user to use standard paper or business forms with the Auto-Com. For children it would allow them to use worksheets and other pre-prepared educational materials. The correction feature would allow the users to back up and correct any mistakes on the same line that they are on. If they have some minimal hand control, they may also be able to operate a paper rolle and correct mistakes on other locations on the page they are working on. The IBM Selectric provides maximum visibility of the typed message and a special "Orator" typeball is available which has 3/16" high letters for easy visibility. The major drawback of this output form is the cost. The Correctible Selectric Typewriter sells for about $625, but the modifications to make it electrically controllable run arund $1500.

Voice Output

One very exciting capability of the Auto-Com is the control of voice synthesizers. Using these aids in conjunction with the Auto-Com, it is possible for a completely non-vocal individual to produce synthetic speech and communicate in a vocal fashion. Moreover, this voice synthesizer can be used in conjunction with the wordmaster option of the Auto-Com so that the user could produce a limited number of vocal phrases by simple pointing to a single square as the Auto-Com. This type of output, however, is not yet practical due to the present high cost ($4,000) of voice synthesizers and their poor voice quality.

Any ASCII Compatible Output Form

Since the output of the Auto-Com is a standard 110 BAUD serial ASCII, it can be used with any communication device which accepts this standard information transfer format. A special adaptor is also available which will convert the serial ASCII into parallel ASCII for use with aids accepting information in that form. Thus the Auto-Com is compatible with most any type of output device as well a most computers. If a code other than ASCII is desired, the Auto-Com can be modified to produce it on a permanent basis through recoding of the reed board, or on a temporary basis using the Wordmaster system. In this manner, the Auto-Com can be used to control any device which uses a 7 bit binary input code.

Control of Other Devices

Because of its ability to produce any 7-bit binary code, the Auto-Com could be used to control many other things besides printout devices. It could be used to control various devices or conveniences in the handicapped person's environment. It could also be used to control specialized machines for education, entertainment or employment. Special codes could also be used to select the mode in which the Auto-Com would be used, so that one board could be used for several functions, including such things as communication, control, entertainment, and self-care.

Radio Transmitter/Receiver

To facilitate communication between the Auto-Com and various output forms, a special radio transmitter/receiver is being designed. The miniature radio transmitter would fit inside the Auto-Com and transmit the control signals to a special FM receiver which could be connected to any of the output forms. This would allow a user of the Auto-Com to control printout devices without having to be connected to them in any way. It would also allow thee user to operate environmental control aids from his Auto-Com from anywhere in the room.

A particularly valuable application of this radio-control option would be in the classroom situation. There a large screen television set with television controller and receiver could be placed in the front of the room. The student with the Auto-Com could then be seated in amongst the other students, while still retaining his ability to ask questions, respond to the teacher or communicate with his classmates by printing his message out on the screen in the front of the room. Several Auto-Coms can communicate with a single TV screen using this system. This would also allow several completely non-vocal children to talk to each other.

SUMMARY

The communication aid described in this paper is capable of providing a protable and independent means of communication to many severely handicapped individuals who have some residual pointing skills. This aid has been designed to be compatible with most standard display terminals to enable ease in the development of a custom communication system for a particular individual. An accessory called the Wordmaster has been developed which enables this aid to operate in a word, phrase or sentence mode of operation as well as the standard letter by letter mode. Provisions have also been made to allow the Auto-Com to be modified easily for use by individuals covering a very wide age range. The aid has also been designed so that it can be used by individuals with different types and degrees of pointing skills. Both speed and cursor mounting variations have been provided for that purpose.

Preliminary evaluation results indicate that the Auto-Com is a decided aid to both the education and personal development of non-vocal severely handicapped children. Its use in the classroom has resulted in the first independent work by the student, more accurate testing, better diagnosis of language problems, more active student time and less one-to-one time required of the teacher. Use of the aid has also fostered both a better self-image on the part of the children and a higher opinion of the children on the part of others.

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A SOURCE BOOK:

DEVELOPING AND IMPLEMENTING A COMPREHENSIVE STUDY OF COMMUNICATION AIDS AS THEY AFFECT EDUCATION AND COMMUNICATION SKILLS OF NON-VOCAL MOTOR IMPAIRED CHILDREN

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A SOURCEBOOK

"Developing and Implementing a Comprehensive Study of Communication Aids as They Affect Education and Communication Skills of Non-Vocal Motor Impaired Children"

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January 1976
Revised December 1976

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FOREWORD

This sourcebook is intended to provide researchers with suggestions and guidelines concerning the development and implementation of a comprehensive evaluation of communication aids. Effort was made to cover all major aspects and procedures involved in such an evaluation. Whenever possible, procedures have been pilot tested and results are recorded herein. For further information, readers are referred to the bibliography, or to the authors.

I. INTRODUCTION

With the passage of recent federal and state legislation, severely handicapped children who have heretofore been excluded from most educational opportunities have now been given the right to enter public school educational programs. A current concern among parents, educators and clinicians involves the ability of school systems to meet the special educational needs of severely handicapped children. Specifically the concern involves educators' and clinicians' preparation to design effective educational programs which will provide these children with the meaningful education which they deserve.

One of the most difficult populations to include in public school programming will be non-vocal severely motorically impaired (NVPH) children. These children are unable to communicate (except through gross gestures and pointing) or effectively interact and transport themselves in their environment without the support of a variety of assistive aids. Although their physical disabilities and need for various therapies may preclude them from complete mainstreaming into regular educational classes, it is their communicative deficit which may preclude them from effective and meaningful interaction in instructional/learning environments.

These children, unable to speak and in some cases unable to gesture or point due to severe motor involvement, require extensive one-to-one instruction and are very dependent upon others to interpret their needs and wants. Their inability to respond in an effective and consistent way to their environment, along with their inability to take tests, perform manipulative tasks, respond to the questions or conversations of others, initiate questions and conversation, or express emotions has, in the past, confined them to a role of relatively passive observance in the classroom. Experimental and interactional deficits have limited their learning and educational progress. In addition, physical and communicative deficits have hindered accurate assessment of residual skills and learning which may have occurred despite those handicaps.

Aids and techniques have been developed which can overcome severe communication deficits in non-vocal motorically impaired children (Vanderheiden, Harris-Vanderheiden, 1975; Luster, Vanderheiden, 1975; Vanderheiden, Luster, 1975). These aids and techniques range from fundamental classroom constructed letter and wordboards to more advanced portable electronic communication aids. Although many of the aids are similar in concept or operation, each is designed a little differently to accommodate children with different handicaps and abilities.

When appropriately applied and integrated into educational programs, communication aids can overcome the severe communication deficits of a great number of NVPH children. It is therefore of critical importance that educators and clinicians learn of these aids and become familiar with how and when to utilize them. Information must be provided concerning the specific characteristics of aids;the aid's usefulness with different populations; its use and value in educational and communication skill programs; its effect upon the child's socio-emotional adjustment; teacher, parent and child reaction to use of the aid; and basic cost/benefit information on the aid. Since many of the aids will be relatively expensive, the educator needs to become aware of those benefits which the aid will provide the child which cannot be attained through other methods.

In order to develop this type of information it is necessary to conduct careful and thorough evaluation of communication aids, documenting their effect upon children's learning and communication processes. At the present time very few aids have undergone use-impact evaluation. Moreover, no in-depth evaluation has been conducted to provide educators, clinicians and parents with comparative information which will allow them to select appropriate aids for different types of children.

II. REVIEW OF PAST AND CURRENT EVALUATIVE EFFORTS

Evaluation of communication aids may be broken down into three basic categories:

1) *field evaluation* of the physical and operational features of specific aids with representatives of the target population for whom they were designed.

2) *comparative evaluation* of different communication aids, evaluating the ability of types or categories of aids to meet the varying needs of NVPH children.

3) *generic, comprehensive evaluation* of communication aids in general in order to determine the value of providing NVPH children with an effective expressive mode, and to determine basic cost/benefit information regarding the educational and communication benefits of effective communication modes.

Currently there are only a few known systematic evaluations of communication aids. This has, for the most part, been more a reflection of how aids have been developed than a lack of efficient rigor in design and development processes. Many commmunication aids have been developed for a specific child or adult, often designed and constructed by a family friend with technical skill. As a result, once an aid was developed, it may have been used by only a relatively small number of people, and no systematic evaluation of the effect of use of the aid was usually conducted beyond that of determining whether or not the aid met the design criteria. Consequently, there are many aids available which could be effective for a great number of NVPH children, but there is little information on them, and there have been few efforts to systematically evaluate their usefulness and applicability as aids to education, communication, and socio-emotional development.

The only known systematic evaluative efforts to date have been those conducted by the Cybernetics Research Institute (Kafafian, 1973), Crotched Mountain Foundation, 1966 , the Trace Center (Harris-Vanderheiden, 1975) and the Tufts Biomedical Engineering Center (in progress). Of these, only the latter two have directly addressed themselves to evaluating the effect of communication aids upon the child's educational progress, language skill and self-concept, as well as evaluating the physical design and operational features of an aid. The

Crotched Mountain study was addressed to an evaluation of "the ability of cerebral palsied persons to manipulate and control a series of switches connected to various output devices (1966), and success in the program was measured by the individual's ability to control one or more of a series of outputs through utilization of an appropriate switch.

The Cybernetics Research Institute included more observation of the use of communication aids for various classroom activities, but major focus was placed upon determining whether or not providing the children with a prosthetic aid allowed them to achieve a "usable and effective written communication capability" (Kafafian, 1973).

Neither of these studies directed major effort toward assessing the educational and communication impact of providing an NVPH child with an effective means of communication. This aspect has been most recently addressed by evaluations conducted by the Trace Center and Richard Foulds (1975). The Trace Center has been involved in field testing of one of their aids, the Autocom, and the New England Biomedical Engineering Center is currently evaluating the Tufts Interactive Communicator (the TIC), a scanning aid.

The studies mentioned above are of the field evaluation type, as each is primarily concerned with gathering field usage information on one aid or one type of aid. To date, there has been no comparative evaluation on the application of different types of communication aids for children with various physical, cognitive and communicative disabilities, nor has there been an evaluation of the overall value and benefit of developing and providing communication aids for the non-vocal severely handicapped child.

Although field evaluation and user impact information is important to educators when assessing the use and application of a particular communication aid (and such studies should be conducted for every aid which is developed), more fundamental information on the use and value of communication aids in general, as facilitators of educational and basic communication and language skills, is necessary. In addition, comparative information on the use of various aids will be critical when educators, clinicians and parents begin to apply these aids and techniques to various populations.

At this point, therefore, the most useful evaluation of communication aids would be a combination of a comparative evaluation and a generic evaluation (hereafter referred to as a Comprehensive Evaluation). The evaluation described in this paper has been developed around a combined comparative/generic evaluation format.

III. METHODS, PROCEDURES AND RATIONALE FOR EVALUATIVE STUDY

There are many factors to consider when implementing an evaluative study which involves non-vocal severely motorically impaired children. Variables involving the physical and cognitive abilities of the children are primary considerations, but of even greater importance are basic considerations pertaining to the overall design of the program. Not only must the population be selected carefully and realistically, but the overall program design must be appropriate to effectively evaluate the characteristics of this population.

Basic concerns and major factors in the design and implementation of an evaluation program of this scope include the following:

1) delineation of the *purpose* and goals of the program,

2) selection of a *framework* within which the evaluative efforts will be most effectively structured (research design),

3) selection of a *population* representative of the target population to whom program results will be generalized,

4) selection of *methods* with which *to obtain evaluative information*,

5) selection of *methods* and procedures with which *to assess learner impact*,

6) selection of *methods* and procedures with which *to analyze results* obtained from the evaluation,
and

7) selection and development of a *format* with which the results of program efforts can be best presented to educators, clinicians and others who will review the program.

Specific objectives for a program designed to study both the application of communication aids in a comparative manner and to conduct a concurrent generic evaluation of the use of such aids would be as follows:

1) to determine the applicability of each of the aids in the study to populations with varying degrees of physical, cognitive and communicative abilities

2) to determine the effect of the use of different types of aids upon the educational and communication skill progress of NVPH children of varying abilities (i.e. to match categories and functions of aids to basic abilities of NVPH children)

3) to determine those educational environments and curricula in which communication aids can be used most effectively

4) to conduct a cost/benefit analysis of the aids, comparing the cost and benefits of educating a NVPH child with an aid to the cost of educating the same type of child without the use of a communication aid (The level of education achieved would be the same for each child in this analysis.)

5) to determine the effect of communication aid use upon the child's social and personal development

6) to determine necessary support and support materials for the effective use of communication aids

A. RESEARCH DESIGN

Criteria for the selection of an appropriate research design, a review of available research designs, and selection of various types of designs which could be implemented in a study of this sort have been studied as part of preliminary research into the implementation of a comprehensive study. A discussion of each follows.

In order to obtain analytic, consumer and appraisal information, and to allow for realistic implementation of an evaluation program of this scope, the following were considered to be basic criteria for a comprehensive research design:

1) the design should allow for maximum generalizability of the results obtained to the NVPH population in general

2) the design must yield both qualitative and quantitative information as to the various aids' effect upon the educational, communication and socio-emotional skills of the learners (i.e. both "how much" and "why" information),

3) the design must be realistic in terms of teacher and parent time and amount of input,

4) the design should be able to be effectively implemented longitudinally,

5) the design should be flexible enough to allow for:
   a) changes in students' physical condition,
   b) changes in students' learning environment
   and
   c) changes in students' residential environments,

6) the design should allow for realistic selection and grouping of the subject population. This is important since the subjects will vary according to:
   a) degree of physical involvement
   b) educational experience
   c) home environment
   d) educational and communication skill
   e) cognitive ability
   f) motivation
   g) educational environment,

7) the design should allow for multiple intervention with a number of different types of stimuli, each with varying characteristics (i.e. it must allow for the use of different types of communication aids),

8) the design must be realistic in implementation in terms of travel and personnel time, and

9) the design should allow for:
   a) charting, tracking and statistical and quasi-statistical analysis of results,
   b) between and within group comparisons, and
   c) pre-, during- and post-test measurements and comparisons.

B. REVIEW OF APPLICABLE RESEARCH DESIGNS

As outlined in Campbell and Stanley (1963), there are two basic types of research designs-- experimental and quasi-experimental. True experimental designs are defined as "designs where the activities of a control group are compared to those of an experimental group " (Campbell and Stanley, 1963). Implied here is the assumption that a single x (or intervention) is compared with no x (no intervention). For study such as that under consideration, this would mean that communication aids would be given to one group of students and their skill progress, etc., would be compared to a group of similar students not using a communication aid. Because of the extreme variance of the population which would be involved in a comparative study of this sort and the difficulty of "matching" experimental and control groups in a manner that would yield generalizable results, alternatives to a strict "experimental/control design" were sought. Other reasons for this decision involve data collection concerns. In order to obtain demonstrable effect of results, the study would need to run for a longitudinal time period. Data collection for the participants in the experimental group would be made easy through the use of data collection devices built into the aid. However, data of comparable magnitude and quality would be extremely difficult to obtain from participants in a control group where no aids are used.

For these reasons the use of quasi-experimental designs was explored (i.e. "designs where full experimental control is lacking, but experimental design is introduced into data collection procedures " [Campbell and Stanley, 1963]). Use of experimental and control groups is not required for this type of design, yet quasi-experimental programs can yield quantitative and statistical information. One basic feature of quasi-experimental designs involves attempts to provide numerous opportunities for measurement of an experimental effect. This is an attempt to try to eliminate rival hypotheses as explanations for the effect. Since it is the goal of the design to attribute results of the experimental effect to a particular intervention, the more implausible the rival hypothesis becomes, the greater the assumption that the effect is due to the intervention. As Campbell and Stanley (1963) have stated:

> The more numerous and independent the ways in which the experimental effect is demonstrated, the less numerous and less plausible any singular rival invalidating hypothesis becomes.

Included in a rationale for using experimental designs which make numerous observations over time is a basic concern reflecting the nature and purpose of the study. In order to evaluate the effect of communication aids upon certain skills of handicapped learners, a number of variables must be considered and the process is a complex one. Repeated measurements over time are needed in order to obtain a representative evaluation of the interaction between the learner, the aid, and the learning environment. Thus, implementation of a design which only affords pre-and post-testing of an experimental and control group (as true experimental designs do) would not likely yield an accurate representation of this interaction. Simultaneous comparision observations of the experimental/control group type are based on the notion that treatments (or interventions) have a certain effect and attempt to measure this. A quasi-experimental design utilizing sequential comparison through repeated measurement will yield an "effect pattern". As this latter type of design yields more comprehensive information, it was felt more applicable for the type of evaluation under discussion.

Quasi-experimental designs which were reviewed and considered for use in this evaluation program were: (Campbell and Stanley, 1963)

1) Time Series Designs

2) Equivalent Time Sample

3) Equivalent Materials

4) Non-Equivalent Control Group

5) Counterbalanced

6) Separate Sample Pre-and Post-Test

7) Separate Sample Pre-and Post-Control Group

8) Multiple Time Series

9) Recurrent Institutional Cycle

A brief discussion of the advantages and disadvantages of the use of each of these designs in a Comprehensive Evaluation follows.

1. *TIME SERIES* $(O_1\ \ O_2\ \ O_3\ X\ O_4\ \ O_5\ \ O_6)^*$ (Campbell and Stanley, 1963)

The essence of the time series experiment is the "presence of

---

Note: With each design a graphic illustration of its implementation will be drawn. Example $(O_1\ X\ O_2)$. These notations are defined as:

X = "exposure to an experimental variable or event, the effects of which are to be measured"
O = some process of observation or measurement
R = Random selection
$O_1\ X\ O_2$ = dashed line between 2 groups indicates groups not equated by random selection
$\overline{O_1}\ -\ \overline{O_2}$

periodic measurement on some group or individual and the introduction of an experimental change in the time series of measurements" (Campbell and Stanley, 1963). When utilizing this design, the researcher selects an intervention (X) and hypothesizes what the nature of that intervention might be. Sequential observations are then made at predetermined time intervals in order to measure the effect of X upon the population. For best predictability, measurements should be taken both before and after the introduction of X (in this case placement of the various communication aids). The intervention (X) must be specified prior to implementation of the program, as should the time relation between X and the "expected manifestation of an effect." In addition, variables which are to be measured must be delineated a priori. See Figure 1 for graphic illustration of example time series experiments.

In a time series design, the value of the intervention is usually measured three ways (Campbell and Stanley, 1963):

1) whether the effect occurs immediately or is delayed,

2) whether the effect demonstrates an increase or decrease in the variables being observed
and

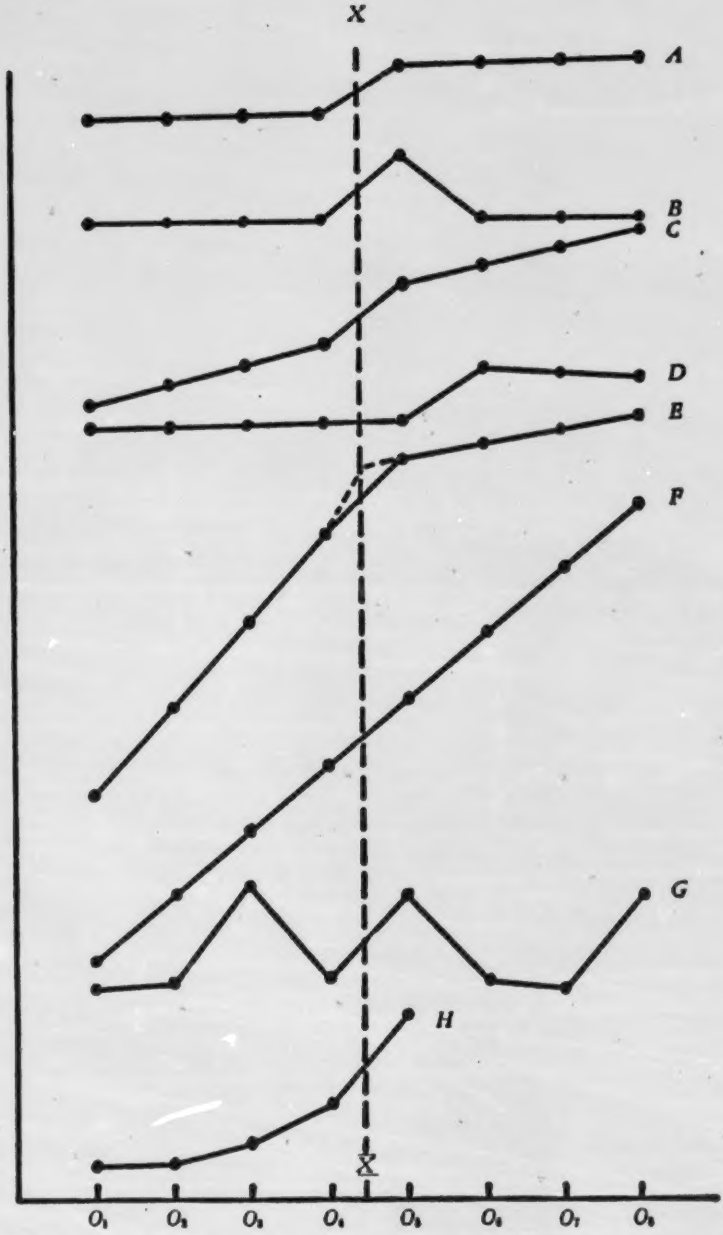
3) whether or not the effect is temporary or long term.

Advantages of utilizing time series over a simultaneous comparison design are numerous. First, time series is particularly appropriate to settings in which "records are regularly kept and are a material part of the environment" (i.e., a classroom setting). Time series also allows for quantitative comparison of treatment effects even though a traditional randomized design is not feasible. Most importantly, the time series design "provides a methodology appropriate to the complexity of the effects of interventions upon individuals or social organizations." (Campbell and Stanley, 1963).

For these reasons, time series is considered a primary candidate for a research design for a study of this sort.

2. *EQUIVALENT TIME SAMPLES DESIGN* (X_1 0 X_0 0 X_1 0 X_0 0) (Campbell and Stanley, 1963)

Review of this design reveals it to be a form of time series design with repeated introduction (X_1) and withdrawal (X_0) of the intervention, and most useful when the experimental effect is expected to be transient. This design requires large, random samplings of time periods, and it is a likely nullifying hypothesis that detected experimental effects may be due to the actual presence of X (i.e. the effects may be occurring simply because X, or the intervention, is introduced so often). Use of this design for an evaluation of communication aids is not considered desirable because of the unrealistic necessity of introducing and removing X (the placement or use of communication aids).



Some Possible Outcome Patterns from the Introduction of an Experimental Variable at Point *X* into a Time Series of Measurements, O_1—O_8. Except for *D*, the O_4—O_5 gain is the same for all time series, while the legitimacy of inferring an effect varies widely, being strongest in *A* and *B*, and totally unjustified in *F*, *G*, and *H*.

FIGURE 1

POSSIBLE OUTCOME PATTERNS

c. Campbell & Stanley 1963

3. *EQUIVALENT MATERIALS DESIGN* (Ma X_1 0 Mb X_0 0 . . .) (Campbell and Stanley, 1963)

This design is implemented in essentially the same manner as the equivalent time samples design, though bases its implementation on the "equivalence of samples of materials (Ma, Mb, etc., above) to which experimental variables being compared are applied" (Campbell and Stanley, 1963). Being very similar to the equivalent samples design, the same restrictions as with the former applied here, and it is not considered to be a useful design for a study of this sort.

4. *NON-EQUIVALENT CONTROL GROUP DESIGN* $(\_\,\frac{0}{0}\,\_\,\underline{X}\,\_\,\frac{0}{0}\,\_)$ (Campbell and Stanley, 1963)

This quasi-experimental design is the closest of those discussed to a traditional simultaneous comparison (or experimental control group) design. Here, two populations are chosen for participation in the study, but do not have pre-experimental sampling equivalence. The groups are usually naturally assembled collectives (i.e. classrooms) and the assignment of the intervention to one group or another is completely random. The more similar the two groups are, the more effective the design implementation will be. The main difference between this and a true experimental pretest-posttest control group design involves randomization of the two participant groups. (In a true experimental design, participants would be randomly selected to one of two groups.) This design is considered viable for implementation in a comparative study, but a time series may be preferred because of the latter design's amenability to continual measurement of intervention effect.

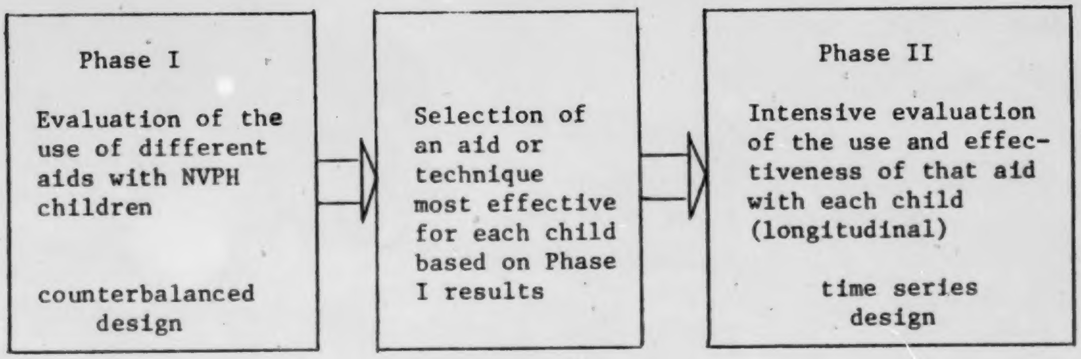
5. *COUNTERBALANCED DESIGN*

(Campbell and Stanley, 1963)

	X_1	X_2	X_3	X_4
A	$t_1 0$	$t_2 0$	$t_3 0$	$t_4 0$
B	$t_3 0$	$t_1 0$	$t_4 0$	$t_2 0$
C	$t_2 0$	$t_4 0$	$t_1 0$	$t_3 0$
D	$t_4 0$	$t_3 0$	$t_2 0$	$t_1 0$

Counterbalanced designs achieve experimental control by entering all subjects into all treatments (Stanley and Campbell, 1963). This design could be interestingly applied as a preliminary evaluation of the use of various types of communication aids with the subject population prior to a comprehensive evaluation. These two programs combined would then yield an immense amount of quantitative comparative information on the value, applicability and effectiveness of various types of communication aids.

A combined program such as this may be illustrated as:


Phase I
Evaluation of the use of different aids with NVPH children
counterbalanced design
Selection of an aid or technique most effective for each child based on Phase I results
Phase II
Intensive evaluation of the use and effectiveness of that aid with each child (longitudinal)
time series design

In Phase One, each child in the program would be given an opportunity to use an aid representative of each of the categories of aids (i.e., if the categories were: direct selection, scanning, encoding and combination, each child would use at least one aid from each of these categories). At the end of the evaluation period (six months - one year) each child would have used a variety of different types of communication aids, and could then be provided with that type of aid which would be most functional for him. Then, a longitudinal evaluation of each child's use of that aid which was considered most appropriate for him would be conducted.

An evaluative program set up like this would allow researchers to conduct two distinct and equally important studies with the same subject population. The first evaluation would yield invaluable information concerning comparative evaluation of the use and applicability of each type of aid with various types of NVPH children. The second evaluation would allow intensive study of the use, effectiveness and value of individual communication aids with children over a longitudinal period of two or more years. From this, the value of providing children with an effective communication aid could be quantitatively and qualitatively assessed.

6. *SEPARATE SAMPLE PRE-TEST POST-TEST DESIGN* $\frac{\text{RO (X)}}{\text{R XO}}$ (Campbell and Stanley, 1963)

In this design, one population is measured on a number of predetermined variables prior to an intervention (X) and another group is measured on the same variables after the intervention (i.e., one half of a class is measured prior to introduction of a reading program and the other half of the class is measured on the same variables after introduction of the reading program in order to measure effect.) This is a simulated pre- and post-test design and is not considered as applicable or rigorous as either the time series or non-equivalent control group design.

7. *SEPARATE SAMPLE PRE-TEST AND POST-TEST CONTROL GROUP DESIGN* (Campbell and Stanley, 1963)

RO (X)
R _ _ XO _
RO
R 0

This design is an extension of the previous design with the inclusion of a selected control group from which the X (or intervention) is withheld. It is similar also to the nonequivalent control group design.

$$\begin{array}{ccc} O & - & XO \\ \hline O & & O \end{array}$$

with the exception that the same specific persons are not retested. As stated with the previous design, it is felt that the time series design would be more applicable and realistic to implement.

8. *MULTIPLE TIME SERIES DESIGN* (Campbell and Stanley, 1963)

$$\begin{array}{l} O_1O_2O_3O_4 \times O_5O_6O_7 \\ \hdashline O_1O_2O_3O_4 \quad O_5O_6O_7 \end{array}$$

This design "combines the time series and nonequivalent control group designs, but the experimental effect is twice demonstrated" (Campbell and Stanley, 1963). The two demonstrations of the effect include:

1) The effect is demonstrated when comparing the activities of the control group vs. the experimental group.

2) The effect is demonstrated when comparing the "pre-x" with the "post-x" measurements within each individual's time series.

Campbell and Stanley feel that this design is particularly appropriate for research in the schools, and it is strongly considered a viable design for an evaluation of the type under discussion (1963).

9. *RECURRENT INSTITUTIONAL CYCLE DESIGN ("PATCHED-UP DESIGN")* (Campbell and Stanley, 1963)

This design is described by Campbell and Stanley (1963) as "starting out with an inadequate design and adding specific features to control for one or another recurrent sources of invalidity". Because it is not felt appropriate or efficient to begin a program with an inadequate research design, this approach is considered inapplicable (at least to start with).

C. SELECTION OF A RESEARCH DESIGN

From this review of experimental and quasi-experimental designs, the following have been selected as appropriate for providing a framework within which to implement a comprehensive study of the use of communication aids:

1) Time Series Design

2) Non-Equivalent Control Groups Design

3) Counterbalanced Design

4) Multiple Time Series Design

Of these four, the counterbalanced design would be most appropriately implemented as a precursory comparative evaluation of the application of communication aids prior to a comprehensive study. Overall, these quasi-experimental designs are considered more appropriate than simultaneous comparison (true experimental) designs as they allow for repeated measurement of an intervention (thus resulting in the documentation of an "effect pattern"), as well as pre- and post-information on the magnitude of an effect. In addition, they are considered more appropriate to the study and quantitative analysis of the complex interaction between children, aids and educational and home environments.

D. VARIABLES INVOLVED IN SELECTION OF SUBJECTS

One of the most important considerations in the selection of a population for an evaluative study is that it should be representative of the target population in general so that results of the study can be easily generalized. This implies that in order to be able to generalize results of a study of the effect of communication aids on the communication and educational skills of NVPH children, the population chosen for the evaluation should be comprised of subjects with as wide a variety of physical, cognitive and communicative skills as those found in the NVPH population in general. Although matching of all of these variables may be unrealistic, selection of the number of variables to be studied and the research design to be implemented will significantly affect the actual diversity of skill levels and chronological and mental ages of students in the evaluation. This section will discuss variables involved in the selection of a subject population. Recruitment of candidates for participation in the program and subject screening processes will not be discussed here.

There are two types of variables involved in the selection of subjects. The first concerns variables which are inherent in the subject population (age, sex, etc.). The second involves variables of the subjects which the researchers specifically wish to study in relation to the effect of intervention.

Variables which are inherent in a NVPH subject population include (among others):

1) Age
2) Sex
3) Type, degree and characteristics of the physical disibility
4) Prior educational achievement
5) Intellectual ability
6) Communicative ability and prior level of attained communication skill
7) Physical abilities
8) Socio-emotional adjustment
9) Parental attitude and expectations

Educational variables include:

1) Educational environment
2) Incoming grade or achievement level
3) Teacher/pupil ratio in present learning environment
4) Type and content of current and past educational programs
5) Supportive services available and participated in
6) Number of assistive aids used by the child
7) Length of educational experience

Of those mentioned, the following variables should be selected a priori and compared throughout the study: 1) age, 2) educational environment, 3) cognitive ability, physical ability, 4) variety of communication background, 5) supporting services, 6) length of educational experience and 7) parental involvement.

These variables must then be worked into two aspects of the overall program. Those which are specific to the subject population must be taken into consideration when deciding upon a research design as the design must allow for handling and analysis of these variables. Those which are of particular interest for comparison among subjects with regard to the intervention need to be taken into account when selecting both the research design and the methods with which data will be collected and analyzed. Failure to control for any one of these variables can have significant impact on the results of the study.

E. EVALUATIVE INFORMATION COLLECTION METHODS

Collecting and systematically recording information of adequate quantity and appropriate quality is often the most difficult aspect of implementation of any evaluation program. In a program such as this with diverse and complex variables, the procedures become even more complicated. In most research designs and evaluation programs, the data is collected by the researchers themselves, thus allowing for rigorous and sophisticated data collection procedures. In an evaluation of the type concerned here, however, the bulk of the data collection may be the responsibility of participating teachers; and thus procedures must remain easy to implement considering the time constraints and other responsibilities of special educators. This section will discuss a variety of methods which can yield effective information concerning the use and application of communication aids when applied by special educators in conjunction with a research team. Included in this section will be a discussion of classroom observation techniques, school and home visits, teacher feedback systems and video and audio tape recordings.

1. CLASSROOM OBSERVATION TECHNIQUES

Observation of classroom interaction can yield two separate but very important types of information:

1) It allows for detailed description and analysis of the teacher/child, peer/child and environment/child interactions.

2) It allows the researcher a tool to observe changes in individual children's behavior (in social/emotional, academic and communication areas).

a. *RATIONALE FOR OBSERVING CLASSROOM INTERACTION*

One of the most effective means of assessing the effect of an intervention upon a child's behavior or interaction is to directly observe his/her interaction with other persons, both at school and at home. As stated by Semmel and Thiagarajan (1973), "Observation systems provide shorthand techniques for describing specific aspects of classroom interaction and behavior in the teaching-learning process." Content free analysis is most appropriate for this as this analysis allows for description of what is happening under different classroom conditions. This is, according to Semmel (1973), useful in any situation which requires an objective and reliable description of interactive behaviors in the classroom.

Observing behavioral interaction within classrooms is an excellent informal means of directly observing a child's behavior without the pressures and tensions involved in testing or standardized assessment situations.

b. *CLASSROOM OBSERVATION TECHNIQUES AVAILABLE*

Carroll (1974) has described one of the most effective techniques for analyzing classroom interaction. The techniques which she describes are based upon an "ecological model" -- a conceptual framework within which the dynamic interaction between the environment and the learning can be discussed and analyzed. Within the "ecosystem" there are ten analyses which can be utilized to assess the learner. Analyses with which to assess the learning environment and the results which they yield are listed in Table 1. Analyses with which to assess the learner and results of such analyses are listed in Table 2.

Carroll's "ecological model" allows classroom observers to objectively analyze both the learning environment and the learner behavior within that environment. These are the most critical features in an effective observational system.

Semmel and Thiagarajan (1973) have discussed two other types of classroom observation systems which analyze teacher and learner separately: Teacher Practices Observation Record (Brown, 1970) and Student Observational Form (Lindvall, Yeager, Wang and Wood, 1970). Sample categories from the Teacher Practices Observation Record are found in Table 3 and Table 4.

TABLE 1

ANALYSES WITH WHICH TO ASSESS THE LEARNING ENVIRONMENT

ANALYSIS	RESULTS
Facility	Information concerning the educational environment -- equipment, aids, size of the classroom, etc.
Personnel	Information concerning teacher/student ratio, available personnel and support personnel.
Process	a) Input -- Information concerning stimuli used in instruction, the cognitive level of input, the rate, amount and sequencing of input. b) Response -- The rate, amount and sequencing of responses. c) Reinforcement -- Reinforcement strategies utilized in the classroom.
Task	Information concerning skills involved in the performance of a task and the main skill required for completion of a task.
Curriculum	Information concerning types and levels of programs implemented and materials utilized.
Climate	Information concerning creativity on the part of the child, the amount of individualization, group activities, interpersonal relationships, etc.
Time	Percent of time spent on academic and other tasks.
Group	Amount of time spent in group work as opposed to individualized work.
Data	Information concerning how data is recorded, what, when, by whom and what form feedback is given to the tasks.

(Carroll, 1974)

TABLE 2

ANALYSES WITH WHICH TO ASSESS THE LEARNER

ANALYSIS	RESULTS
Status	The child's level of achievement and/or a discrepancy in level of achievement versus potential.
Avoidance	Specific subjects, tasks, settings or people avoided by the child.
Personnel	Persons with whom the child learns best.
Situational	Analysis of the environments in which the child learns.
Time	The time of day that the child learns best and degree of perseveration.

(Carroll, 1974)

TABLE 3

SAMPLE CATEGORIES FROM THE TEACHER PRACTICES OBSERVATION RECORD

I. Nature of the Situation

T occupies center of attention.
T makes P center of attention.
T makes some thing as a thing center of P's attention.

II. Nature of the Problem

T organizes learning around Q posed by T.
T organizes learning around P's own problem or Q.
T prevents situation which causes P doubt or perplexity.

III. Development of Ideas

T accepts only one answer as being correct.
T permits P to suggest additional or alternative questions.
T expects P to come up with answer T has in mind.

IV. Use of Subject Matter

T collects and analyses subject matter for P.
T has P make his own collection and analysis of subject matter.
T provides P with detailed facts and information.

*Brown, 1970.

TABLE 4

SAMPLE CATEGORIES FROM THE STUDENT OBSERVATIONAL FORM*

I. Independent Work

The student is reading independently.
The student is working independently on a worksheet.
The student is individually listening to a tape recorder.

II. Teacher-Pupil Work

The pupil seeks assistance from the teacher.
The pupil receives assistance from the teacher.
The pupil discusses his progress with a teacher.

III. Non-Instructional Use of Pupil Time

Pupil spends time at desk not working.
Pupil waits for teacher or clerk to provide lesson materials for him.
Pupil waits for prescription.

IV. Pupil-Pupil Activity

Pupil asks assistance from another pupil.
Pupil received assistance from another pupil.

V. Group Activity

Pupil contributes to a group discussion.
Pupil takes a group test under supervision.
Pupil answers a question directed to him.

*Lindvall, et al., 1970.

Other systems described by Semmel include the Flanders System of Interaction Analysis (Flanders, 1970) (Table 5) and the Indiana Behavior Management System (IBMS) (Fink and Semmel, 1971) (Table 6). Both of these systems analyze both teacher and student behavior concurrently. The IBMS differs slightly, however, in that the behavior of only one child is recorded at any certain time.

Although all of the systems described above would be appropriate for the analysis of classroom interaction in an evaluation of this sort, the Carroll "ecosystem" model would be most appropriate for an analysis of the learning environment and the learner's interaction in that environment. The IBMS would be an appropriate measure for concurrent analysis of both teacher and pupil behavior, and the Teacher Practices Observation Record and Student Observational Form would be appropriate for separate analyses of teacher and student behavior. These methods would be useful in evaluating the impact of a communication aid upon a learner's educational progress and environment.

c. *METHODS AND PROCEDURES FOR RECORDING BEHAVIORAL OBSERVATIONS*

Methods and procedures for recording behavioral observations in classrooms may include the following:

1) Continuous Recording. This type of recording involves continuous observation of a child and notation of his interaction with the environment. Usually one or two variables regarding this interaction are delineated and observed during the day.

2) Home Visits. In addition to information and analysis generated from classroom observation techniques, home visits and parental interviews supply an important source of feedback as to the child's use (or non-use) of the aid in the home as well as parent and sibling reaction to the aid. Pilot programs have shown that integration of the aid into daily family activity can play a crucial role in its overall effectiveness and impact on the child's language and social/emotional skill development. Pre-arranged visits and periodic phone calls are invaluable to the evaluation procedure.

3) Teacher Feedback Systems. One of the most important aspects of an evaluation program conducted at some distance from the core research team is teacher feedback. Pilot experimentation with teacher feedback systems has shown that those systems which enable teachers to respond with minimum effort and in a short period of time are most effective. The feedback system should allow for quick and immediate recording of observations and should not require lengthy writing. Those methods which have been shown to be most effective include:

   a) Weekly and periodic phone calls
   b) Tape recorded (cassette) feedback
   c) Multiple choice questions
   d) Recorded teacher interviews

Weekly and periodic phone calls should be made at a regular, pre-established time with the teacher, and questions to be posed should be written prior to the phone call. In addition to allowing evaluative feedback, this method allows researchers to keep close monitor on any maintenance problems that may arise in the communication aid itself.

Tape recorded cassette feedback allows both research team and teachers to pose or answer questions. Typically, a tape would be sent to the teacher with three or four questions which could be answered on the teacher's own time. In addition, the recorder could be placed in some convenient place in the classroom; and when some event worth noting occurred, the teacher could simply walk to the recorder and note the observation. With this type of immediate and easy event recording, teachers would be able to log observations more frequently and more accurately than when waiting until the end of the day to complete a daily questionnaire. Researchers would also be able to tape replies to teacher questions, thus retaining dialogue through methods other than phone calls.

Multiple choice questionnaires with options for additional comments and recorded teacher interviews allow collection of information supplementary to that collected through the above methods.

4) Audio-Visual Recording Techniques. In addition to the audio recording described above, visual recording through either videotape or super 8 mm. movies provides an excellent medium through which to record and store visual record of children's progress with a communication aid. Visual recording is especially useful for documenting changes and/or improvements in the child's physical skills. Video recording affords analysis of events or behaviors after recording is complete and also allows researchers to run reliability checks on their observations by having a third party also record the specified events while viewing the records independently. In order to be of maximum use, however, events and behaviors to be observed and recorded need to be completely specified prior to filming. The filming should be done when the child is apt to perform maximally and when researchers are fairly certain that the recording will not disrupt normal behavior and thus produce inaccurate data.

5) Automatic Data-Recording Aids. Data-recording aids which can be inserted into some of the advanced electronic aids are now possible. These units can automatically record much data which is usually recorded manually. For a more complete discussion of these units, the reader is referred to Appendix A.

Any one of a number of these or other data collection techniques can be useful in a comprehensive evaluation. Selection of procedures is usually made depending upon the quantity of data desired and the amount and extent of teacher and parent cooperation that exists between field centers and the research team.

In addition, educators and field data collectors may feel more comfortable with particular procedures. Researchers may then need to develop a number of different procedures (which will yield the same type of information) in an effort to accommodate educators' preferences.

F. SELECTION OF METHODS AND PROCEDURES TO ASSESS LEARNER IMPACT

Assessing learner impact may be accomplished through behavior rating scales or tests and evaluations. Each of these methods will be discussed in this section.

1. *BEHAVIOR RATING SCALES*

Behavior rating scales offer a mechanism whereby researchers or teachers may inventory or rate the impact of an intervention upon a child's learning growth. Most often teachers will complete the scale (as opposed to researchers) as teachers spend much more time interacting with the child and have more opportunities to observe, assess and record changes in behavior.

Behavior rating scales may be used to chart developmental successes of the child over long periods of time or may be used to scale or rate children's progress prior to and after a certain intervention.

Most behavior rating scales appear in inventory form and are applicable for observing NVPH children's interaction and learning within the classroom setting. A review of some of the more common rating inventories follows.

1) *Classroom Behavior Inventory*
(Schaefer, Aaronson and Burgoon, 1965)

This inventory consists of 320 items on 64 scales broken down into components such as achievement orientation, concentration, attention seeking, etc. The inventory offers a method for systematically collecting behavior ratings on social, emotional and task oriented behavior in the classroom.

2) *Deverux Elementary School Behavior Rating Scale*
(Spirack and Swift, 1967)

This scale defines and classifies disturbed classroom behaviors and contains 111 items. The scale is divided into two sets (I and II). Set I is constructed on a five-point scale and measures frequency of occurrence of the behavior, and set II is a seven-point scale of the degree of behavior disorder. Creative initiation, class disturbance, need achievement, defiance, etc., are measured.

3) *Children's Behavior Questionnaire*
(Rutter, 1967)

This is a short response questionnaire for children between seven and 13 years and consists of 26 statements rated on a three-point scale. The scale rates behaviors which occur within school settings and is used to discriminate between different types of behavior and emotional disorder.

4) *Haggerty-Olson-Wickman Rating Scales*
(1930)

This scale "provides a clear picture of weaknesses and assets of children which may be used as a basis for a program of reconstructive education" (1930). The scale has two schedules, A and B. The A schedule rates general behavior with 15 items, and the B schedule rates intellectual, physical, social and emotional traits with 35 items.

5) *Pupil Behavior Rating Scale*
(Bower, 1960)

This scale was developed for in-school screening of children who may have emotional handicaps. It can be administered to children and young adults in grades K-12.

6) *Child Behavior Rating Scale*
(Cassel, 1960)

This scale measures children's ability to "adjust in home or school settings". It includes categories of self, home, social, school and physical.

7) *Behavior Classification Project Inventory*
(Dreger, et. al., 1964)

This inventory is a measure of emotional behavior and is appropriate for children from six to 13 years. Scores are marked yes or no as to whether or not a certain specified behavior has occurred in the past six months.

8) *Behavior Problem Checklist*
(Peterson, 1961)

This checklist defines 56 common behavior problems and rates them on a three-point scale. Primary application of the checklist involves screening behavior problems in children between Kindergarden and sixth grade.

9) *Classroom Behavior Checklist*
(Schaefer, et. al., 1968)

This checklist consists of 17 scales which systematically rate social, emotional and task-oriented behaviors of children in the classroom. The checklist has primarily been used to facilitate screening and as a predictor of classroom adjustment behaviors.

Of those checklists and inventories reviewed, those most appropriate for assessing the impact of use of a communication aid upon a child's classroom behavior include the Classroom Behavior Inventory, the Deverux Elementary School Behavior Rating Scale and the Classroom Behavior Checklist. The others reviewed may be useful in assessing the impact of use of a communication aid upon a child's social or emotional growth.

2. *FORMAL AND INFORMAL ASSESSMENT MEASURES*

Tests and evaluation measures appropriate for assessing learner impact fall under two major categories, formal and informal tests.

Formal measures are those tests which usually constitute a psychological examination administered by a school or clinical psychologist. Informal measures would be those assessments and evaluations which are either individualized adaptations of standardized tests or teacher-constructed tests.

In a pilot evaluation of the use of communication aids, formal tests were utilized to measure learner impact on a global basis. Formal tests included in the psychological exam included:

1) Peabody Picture Vocabulary Test (Dunn, 1959)
2) Raven Progressive Matrices (Raven, 1960)
3) Knox Cube Test (Arthur, 1947)
4) Columbia Mental Maturity Scale (Burgemeister, Blum and Lorge, 1972)
5) Peabody Individual Achievement Test (Dunn, 1970)

Although scores did show improvement after the children had used communication aids, test scores were not detailed enough to help teachers or researchers determine specific impact of the aids. In addition, test results were not felt to be indicative of the students' ability as the tests were designed to be administered to normal vocal and manipulative children. Utilization of individual teacher-made test results to assess specific impact were helpful in assessing individual child progress but were inapplicable for comparing progress between children as no two teachers developed the same tests.

In an effort to circumvent these testing problems in future evaluations, an informal assessment battery designed to assess the basic academic skills of NVPH children was researched and developed. A report of the development of the informal assessment battery has been included in Addendum A.

IV. A MODEL FOR IMPLEMENTATION OF A COMPREHENSIVE EVALUATION

An example comprehensive evaluation of communication aids has been outlined and is comprised of three phases of evaluation and tracking. Phase One involves administration of baseline academic and communication skill inventories and complete documentation of the child's skill in these areas as well as social/maturational and environmental and personal interaction areas. Also during Phase One the child would use a number of different communication aids -- each with different modes and physical features -- which the child is able to operate effectively. At the end of Phase One (six months to one year in duration), the communication aid which was most beneficial to and effective for the child would be selected for his continued use. Phase Two would involve close tracking of the baseline skill areas while the child used the communication aid. Phase Three would involve continued tracking of each child's use of the aid, analysis of each child's progress and comparison of progress (where appropriate) and documentation of the program. Further details on potential implementation of these phases follow.

A. PHASE ONE

The counterbalanced quasi-experimental research design mentioned previously could be used here to track and evaluate children's efficient use of and progress with a particular communication aid. At the end of this phase and after the children have used aids which offer different approaches to providing alternate communication response modes, one aid would be chosen for use with each child. A particular aid's applicability and use with different types of children could be summarized from the data gathered in the counterbalanced design. Also during this period the child's previous educational and communication skill would be thoroughly documented as well as his skill level at the beginning of the program (measured through a baseline diagnostic inventory). In addition, the child's present educational and communication skill would be closely tracked and documented prior to his use of any communication aid. Components necessary for the implementation of Phase One include the following:

1. BASELINE MEASUREMENTS OF A CHILD'S SKILL

These baseline measurements would be assessed through a baseline diagnostic inventory and continued tracking of the child's skill for a pre-determined period prior to his acquisition and use of an aid. Skills assessed through the inventory and during the baseline period would include:

1) Physical and motor coordination skills (as assessed by a physical or occupational therapist).

2) Auditory and visual skills (to include measurements of both acuity and perception).

3) Communication and language skills (comprehension, production and expressive skill).

4) Basic academic skills (math, reading, language arts).

2. *ANALYSIS OF THE CHILD'S EDUCATIONAL ENVIRONMENT AND BACKGROUND*

This would comprise part of the documentation of the child's past and present abilities and achievement prior to use of the aid. Included here would be observation and documentation of the child's classroom facilities and activities, peer number and educational level, teacher-student ratio and support personnel and facilities available to the child. In addition, the child's past educational environment would be documented through contacting past teachers, clinicians and schools.

3. *ANALYSIS OF THE CHILD'S LANGUAGE AND COMMUNICATION ENVIRONMENT AND BACKGROUND*

This would comprise the other part of the documentation of the child's past and present abilities and achievements specifically in the area of language and communication. Here the child's previous communication modes would be explored as well as the success of each. His home environment and influence of this environment upon his language and communication development would be explored and his past and present speech and language activities would be documented.

4. *QUANTITATIVE MEASUREMENT OF CHILD'S SKILL LEVEL*

During Phase One the following quantitative measurements would be obtained for each child:

1) Neuropsychological examination of the child by an independent testing center

2) Communication performance test (i.e., rate, speed and quantity of present communication)

3) Criterion referenced skill profiles in the areas of math, reading comprehension and reading skills

4) Speech and language assessment tests

5) Tests of cognitive development

5. *QUALITATIVE FEEDBACK ABOUT EACH CHILD'S EDUCATIONAL AND COMMUNICATION PROGRESS PRIOR TO HIS USE OF AN AID*

Here, teachers and parents would supply qualitative feedback concerning the child's educational and communication skill progress through structured interviews, periodic questionnaires and teacher-taped cassette recordings.

6. *TRACKING EACH CHILD'S SKILL PROGRESS PRIOR TO USE OF AN AID*

During Phase One the child's skill progress could be tracked and documented through:

1) Teacher-taped cassette feedback.

2) Teacher documentation of classroom activities.

3) Tracking and analyzing daily classroom and academic skill progress feedback.

4) Teacher feedback of mastered skill areas and curriculums.

5) Teacher questionnaires.

7. *SITE VISITS*

Throughout Phase One the research team would make periodic site visits to field placements in order to document the program through films and tapes and to keep in contact with teachers.

B. PHASE TWO

Phase Two involves close tracking of the child's skills while he is using a communication aid. Components necessary for implementation of this phase would include:

1) Study of the Child's Ability to Use the Aid

The amount of time it takes the child to learn to use the aid would be measured, and periodic objective assessments of his increased ability to use the aid over time would be taken.

2) Quantitative Measurement of the Child's Skill and Skill Progress After He Has Acquired Competence with the Aid

This component is majorly comprised of systematic, sequential administration of criterion-referenced tests.

The first criterion-referenced test administered would be the baseline diagnostic inventory and would be used to supplement the baseline profile obtained for all the children.

There would be two other criterion-referenced test batteries labeled, at this point, Form A and Form B. Form A would be administered by the Trace Center staff, and Form B would be administered by the child's teacher. Form B, shorter than Form A, would be designed to give corroborative data to Form A based upon teacher assessment of the same skills. This separate but related assessment is important as it has been shown that children often perform poorer on tests administered by unfamiliar persons.

Also, in an effort to avoid learner familiarity of test problems and skill tasks, two versions of Form A would be developed. Each version would contain the same number and level of skill tasks and the same degree of difficulty. Essentially, a battery of skill tasks would be developed for various skill levels and degree of difficulty and then randomly assigned to version one of Form A (A1) or version two of Form A (A2). Thus, the content and comprehensiveness of each test version would be the same but skill tasks would differ slightly so as to discourage learner familiarity or memorization of skill tasks.

3) Qualitative Feedback of the Child's Educational and Communication Skills While Using the Aid

Qualitative feedback in Phase Two would be obtained from teachers and parents in the same manner as Phase One -- through structured, tape recorded interviews and periodic questionnaires.

4) Cost/Benefit Study

During Phase Two a cost/benefit study of the importance and value of communication aids as aids to education would be conducted. This would involve analyzing educational programming costs for the non-vocal physically or multiply handicapped, analyzing classroom and teacher time expenses, studying the child's skill progress without the use of a communication aid and studying the same with the use of a communication aid.

5) Tracking the Child's Skill Progress After He Has Acquired Competence with the Aid

Tracking skill progress would be accomplished through recording feedback from teacher-taped cassettes, filming of students, tracking classroom activities, recording and analyzing information from the data recorder, teacher questionnaires, criterion-referenced skill tests and periodic school and home visits.

6) Teacher Information Exchange System

Throughout Phase Two information would flow to and from the teachers through regular phone calls, mailings to and from school, quarterly reports, taped cassette feedback and school visits.

7) Site Visits

Regular site visits would be made to all field placements in order to document program progress, administer tests and exchange necessary information with the teachers.

8) Teacher and Parent Progress Report Seminars

Twice during Phase Two all teachers and parents would be asked to attend a progress report seminar. This seminar would be an invaluable opportunity to inform teachers and parents of program results and possible program modifications. It would also serve to answer their questions and all parties would exchange information and reactions to the program and the children's progress.

9) Student Feedback System

Students would share in an information exchange through a bi-monthly student newsletter.

10) Maintenance of Aids and Aid Interfaces

Throughout Phase Two all communication aids interfaces would be maintained, repaired and sent back to the schools as soon as possible. If an aid would go down, a back-up aid would be immediately provided for the child so that he needn't be without communication until his is fixed.

Although not a particular component, throughout Phase Two researchers could also be exploring and developing educational programs for use with the communication aids. These programs would be developed through working very closely with the teachers and educational program specialists.

C. PHASE THREE

Phase Three would primarily involve continued long-term tracking of each child's progress (though in a less formal way) and complete documentation of the Comprehensive Evaluation Program

V. SUMMARY AND CONCLUDING REMARKS

As stated earlier, information on the use of various communication aids with NVPH children who vary according to physical and cognitive ability and age is desperately needed by educators and parents. There are a number of aids currently available and more being developed. Providing augmentative communication to NVPH children through use of different types of communication aids is a relatively new concept, and most educators and parents will be overwhelmed with the variables involved in selecting the appropriate aid for their child. Results of a comprehensive evaluation such as that outlined here will be a major first step in providing these persons with basic information on the use of aids in general and the use of different types of aids with children who have various types of handicaps. With this information, types of aids which appear to be most applicable to specific children's needs could be selected.

This sourcebook has attempted to provide researchers with basic information needed to develop and implement a comprehensive evaluation of communication aids. It has not been intended to provide a blueprint for such an evaluation but rather to provide suggestions, guidelines and ideas.

The reader is encouraged to consult the references listed and/or the author if additional information is desired.

APPENDICES

APPENDIX A

DESCRIPTION OF A
DATARECORDING AID

DATARECORDING AIDS

What is the Trace Datarecorder?

The Trace Datarecorder is a sub-miniature cassette tape recorder which fits into a special cartridge. This cartridge then slips into the upper right hand corner of the Autocom (Figures 1 and 2).

What does it do?

The Datarecorder will record in digital form all the messages which are printed on the Autocom. In addition to recording all of the output from the aid, the Datarecorder will automatically mark off one-minute time segments on the tape to aid in taking time samples and establishing time of day.

Why is it needed?

One of our major concerns right now is studying language development processes in non-vocal motorically impaired children. For this we need accurate information on what the children say, or produce, and the context and manner in which they say it. We tried to obtain this information from the thermal print tape, but it wasn't accurate enough as we could not tell what transpired prior to the outprint of the message (i.e., we couldn't tell which mistakes had been corrected).

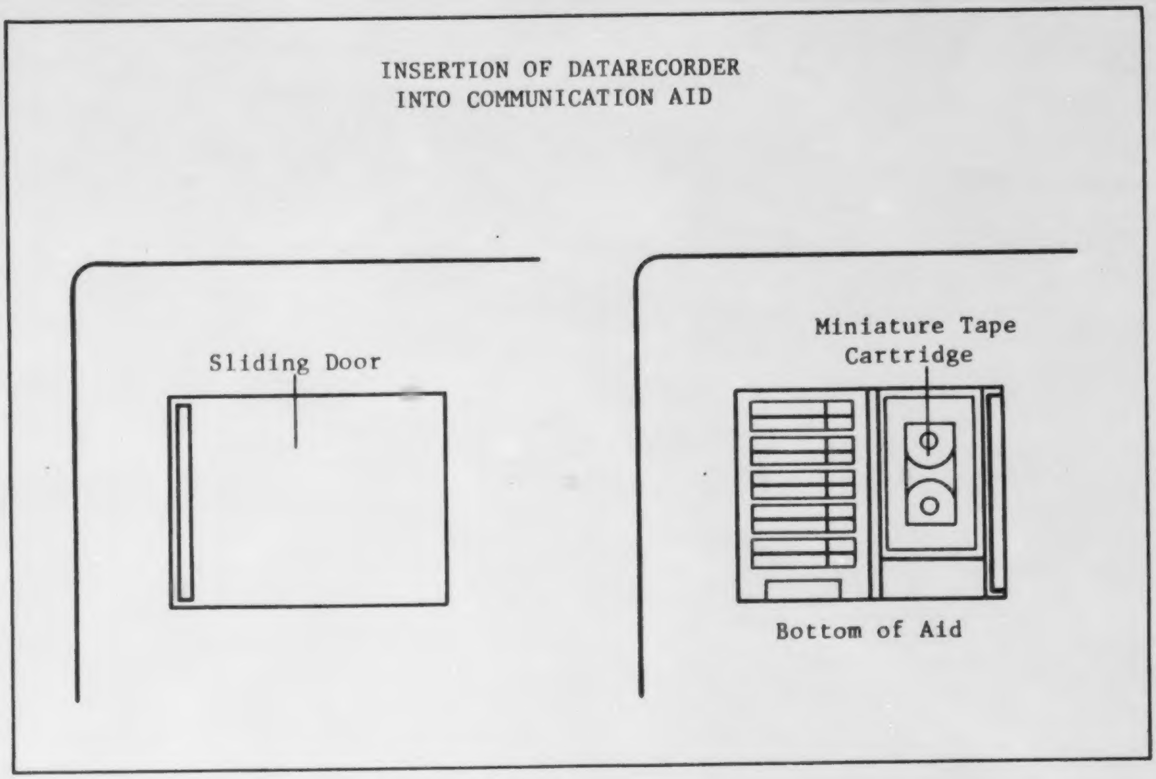
The Datarecorders were developed so that we could obtain much more detailed information without necessitating laborious teacher-written language samples.

What information can be obtained from the Datarecorders?

All of the Datarecorder information will be logged on a sub-miniature tape cassette. This tape will then be fed into a computer which will analyze and reconstruct the information for us.

Because every minute will be "marked off" on the tape, we will be able to combine any number of these minutes into time samples (similar to the five-minute samples we collected previously in our pilot studies). In addition to time sampling information, we can obtain the following:

1) vocabulary and word frequency counts
2) grammatical usage frequency
3) amount of time needed to construct the message
4) number of errors in the message
5) number of corrections made in the message
6) tally of spelling errors
7) number of unique words printed
8) average number of words in sentences
9) average number of letters in words



INSERTION OF DATARECORDER
INTO COMMUNICATION AID

Sliding Door
Miniature Tape Cartridge
Bottom of Aid

FIGURE 2

These are a few examples of information which we can obtain. All of this information is crucial to the study of language development in non-vocal children.

What if the student doesn't want us to know what he is saying?

The Datarecorder can be "turned off" at any time, and the student can delete certain messages from the transcript. To turn the Datarecorder on and off, a code is printed before and after the "private" message.

CODE = [[. . . . .]]

Example: message to be deleted = I love you

[[I love you]]

What do I (as a teacher or parent) need to do?

Every two weeks the Datarecorder tapes (inside the cartridges) must be changed. We will supply the tapes for you. Steps for changing the tapes are:

1) Open sliding door

2) Remove tape cassette

3) Date the tape and label with the student's name.

4) Date the new tape and insert it into the aid. (Push firmly when inserting the tape).

5) Close sliding door.

6) Send the dated and labeled tape back to Trace Center.

If you have questions or problems at any time, please don't hesitate to call Deb Vanderheiden at (608) 262-6966.

APPENDIX B

EVALUATION IMPLEMENTATION PROBLEMS AND RECOMMENDATIONS FOR FUTURE PROGRAMS

EVALUATION IMPLEMENTATION PROBLEMS AND RECOMMENDATIONS FOR FUTURE PROGRAMS

As mentioned earlier, attempts to test run meaningful quantitative rate data collection procedures with the population in this study were unsuccessful. The following discussion summarizes problems that were encountered in this program as well as other potential problems identified. Suggestions are provided for trying to implement evaluation programs involving the collection of learning rate or other quantitative data on impact of the aids with non-vocal multiply handicapped children.

The principle problem areas identified in this study were:

1) Variability and Dropout/Return of Children
2) Irregularity and Changes in Education Programming
3) Evaluation Measures
4) Program Implementation

Children

One of the largest problems in developing a program to study the effect of (something) on the development or rate of learning of severely/multiply handicapped children is the extreme variability of the children. Physical, cognitive, family, support services, educational program, educational history, past experience, communication skills, social skills, health, vision, hearing, motivation and emotional maturity are only some of the many variables which must be considered and controlled for. These children are much more prone to problems in these and other areas and seem to be much more (totally) affected and affected for a long time by these problems than normal children.

As a result, it is not possible to pair children for control and it is common to lose data for extended periods of time due to complications in the children or their lives. The unpredictability of this later problem is currently worsened by the very dynamic and frequent changes that are occurring in the children's lives as people try to comply with recent legislative mandates.

Educational Program

In addition to the child variables, one also has to be prepared for the variations in the children's programs. Effective and defined programs for these children are only now beginning to be formulated. As a result, teachers are rapidly changing their educational programs as they try to find programs and approaches which are meaningful and effective with these children. This makes it extremely difficult to provide any organized approach to tracking their progress in specific areas. Since no instruments exist which can be used effectively with these children, they must be created or modified by the research program staff. With frequent program changes occurring, it is not possible to have effective tracking instruments ready unless close cooperation is maintained throughout this process. A close working relationship and an understanding by both the teachers and the researchers of the constraints imposed by the educational process and research design is critical to a successful program.

Even careful pre-arrangements, however, can run into problems where children change teachers or classroom during the study. Since most of these studies will occur over more than a one-year period, this is not only possible but probable. In addition, the entire programming approach in which the child is enrolled may change as the schools move to better meet their educational mandates and priorities.

Evaluation Measures

Because of the severe handicaps of the children, both physical and in terms of past educational experience, the rate of change in the beginning is likely to be very slow. As a result, the test instruments will have to be fairly sensitive. It is currently difficult to develop such tests since very little is known about the development of skills in the areas of language, mathematics and general cognitive functioning for these children who have little if any ability to express or use language or to interact with or manipulate their environment. Preliminary efforts to develop effective measures for these children suggest that the order of acquisition of skills may differ from that which is measured in normal children. There is some indication that the children develop alternate strategies for answering questions and are successful at doing so for items which are beyond or based upon other items which they fail, but which need be considered necessary concepts for the items passed.

Formal tests, even adapted formal tests of general ability, prove to be of little benefit in the study. A series of six tests including the Peabody Picture Vocabulary Test, the Raven Progressive Matrices Test, the Knox Cube Test, the Columbia Mental Maturity Scale, the Peabody Individual Achievement Test, and the Boston Speech Sound Picture Test were given to each of the children on a pre and post basis. Results of these tests show little, if any, significant progress. More importantly, the variability of achievement even within subsections of each test demonstrate the variability of the performance due to artificial factors. A summary of the results of the testing are provided in Addendum A. of this report. At the request of the tester, no further summarization is provided here.

Because of the lack of formal test materials for these children, either informal testing or adaptations to formal tests (which render them informal) appear to be the most appropriate way to proceed. The diversity of the children's skills and skill levels, however, will require that the children be carefully selected to be in approximately the same skill range. If not, then extensive periods of time and effort will be needed to develop the different tests over the very broad ranges that these children exhibit. The measures will also have to be made quite flexible in order to be able to accommodate wide fluctuations in the abilities of these in the same child over time. Since the children also appear to develop interesting strategies for correctly solving problems or answering questions while lacking a firm understanding of the basics involved, measures should include items which carefully cross-check skills for acquisition.

In addition to the content to problems involved in the design of effective measurement instruments, there are also significant implementation problems due to the severe communication and manipulation handicaps of the children. This is especially true for data being taken during the baseline period when the child has no independent means of clearly responding or imitating choices. The usual techniques of sequential presentation of multiple choice greatly limit the types of language and other skills which can be measured. They provide the child with the correct answer which must merely be identified rather than produced and they are very prone to inadvertent cueing, especially when even the child's yes and no may need to be interpreted by the tester due to the child's physical involvement. Many of the children have developed marvelous strategies for reading their testers and frequently show increases in physical control when working on difficult problems further masking their yes and no responses.

Program Implementation

Many problems arose or were more difficult to handle as a result of the means in which the program was implemented. One of the most critical factors was the distance between the research group and the field evaluation centers. Whereas this facilitated the independent use of the aids and did not hamper the collection of qualitative information on the effectiveness of the aids, it posed severe problems in the collection of the quantitative data. This is especially true where classroom problems reduced the ability of the teacher or staff of the school to take the data themselves. The distance also caused delays in notification of particular problems which arose during the study.

A second situation which should be avoided is the changing of the project personnel which means contact with the schools. A rapport and feeling of continuity are critical to trying to maintain contact effectively with the teachers and to conducting research in an educational setting. In addition, the teachers themselves should be brought into the data collection design procedure and should be considered members of the research team implementing the program.

Because of the variability and severe handicaps of the children, this study should be designed to cover a fairly extensive time period. Of particular importance is the baseline period. Past records of the children's abilities and learning achievements are of little or no use as quantitative data. Often, the first thing that is discovered after providing the communication aid is that the children have not progressed nearly as far as was previously thought. As a result, a sufficiently long and very carefully tracked baseline period will be essential to any useful rate change study. This may, however, prove to be the most difficult part of the study once teachers are informed of an aid which could provide their children with an effective means to communicate and interact. It is very difficult or impossible to convince them that they should wait a year or two while you secure funding, develop the measuring instruments and conduct the baseline period before allowing their child to secure one of the aids.

Suggestions for Future Research Studies

The following suggestions for implementation of teacher evaluation studies designed to collect quantitative data on changes on rate of learning have been developed as a result of the evaluation program and the preliminary work on the preparation for the comprehensive evaluation program:

> Close proximity of field centers to research center - in order to facilitate intercommunication with teachers and to back up collection of data by teachers, this problem arises (be sure to have prearranged clearance to do so)
>
> Simple flexible design - which allows for dropout and return of subjects and which compares child chiefly to himself
>
> Simple data collection - which can be implemented by research staff if need be and only includes collection of absolutely essential information by teacher and research staff
>
> Selection of roughly equal children - in order to greatly reduce the range of evaluation instruments which will need to be designed and developed
>
> Long baseline period - which allows for dropout and return of subjects and which does not rely on past records of children for quantitative data
>
> Avoid promising a placement date for the aid until all baseline data are in hand and confirmed
>
> Appropriate length for study in order to ensure that moderately sensitive instruments will be able to effectively measure change. This same constraint applies to the baseline period
>
> Time to design measurement instruments - such that all instruments can be completed and tested prior to the initiation of the baseline period

Teacher involvement from start - involved in planning of the program so that researchers are aware of constraints in individual classrooms and so that teachers understand and accept the constraints of research

Teacher feedback - a strong, effective, meaningful tool for feedback of results of the study throughout the study. If pre-release of results may bias outcome for study, then provisions should be taken in that regard. The teacher, however, must feel that s/he is part of the team for an evaluation program which has many potential problems as these have to succeed.

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ADDENDA

ADDENDUM A

TOWARD DEVELOPING A DIAGNOSTIC BATTERY OF BASIC ACADEMIC SKILLS FOR NON-VOCAL PHYSICALLY HANDICAPPED CHILDREN

I. INTRODUCTION

A. Purpose of the Baseline Inventory

A major goal of a comprehensive evaluation program is to ascertain the effect of communication aids upon a child's educational development. As part of this goal, there is a specific objective of evaluating the effect of communication aids upon the child's progress in basic skills. To assess the child's progress, it is necessary to have a detailed record of his academic skills before he receives the communication aid. Then, further assessments can be compared to the list of skills he had achieved prior to receiving the aid.

As part of a comprehensive evaluation program, therefore, a Baseline Diagnostic Inventory should be administered to each student before he receives an aid. This diagnostic inventory would cover the basic skills which are universal to elementary school curricula: arithmetic, reading comprehension, and reading skills. It would extend across a wide range of academic levels in order to be applicable for all of the students involved in the study.

B. Problems With Available Achievement Tests

In the process of gathering tests to be included in the Baseline Diagnostic Inventory, it became apparent that the majority of achievement tests that are currently available are inappropriate for the non-vocal, severely motorically impaired student. (See Section IIB - "Search of the Literature.") It is extremely difficult to accurately assess the skill achievements of these handicapped students through standardized achievement tests for several reasons.

In general, standardized achievement tests have the following problems:

1. They are norm-referenced to the population of normal, vocal, physically intact children.
2. They require oral and/or written responses.
3. They often have time limits.

The most common method of interpreting standardized test scores is with norm-referencing. For a norm-referenced test, the individual's score is compared to those of other individuals (known as the norm group) which usually is composed of the normal school population. In terms of testing the non-vocal severely handicapped child, norm-referenced test scores seem to have little value. As Cruickshank notes (1971, p. 341), ". . . standardized measurement may be less informative about the cerebral palsied child than other children. The pervasive physical, social, and neurological effects of this disability usually generate such great differences from the usual in the testing situation that comparisons with non-disabled norms and the imposition of ordinary testing procedures become exceedingly risky."

The second major problem with standardized tests is that they generally require extensive oral and/or written responses. For these students, it would be a physical impossibility to take a typical assessment battery. Since these students are non-vocal, they are unable to respond orally, and they lack sufficient control to write or type.

In addition, a number of tests impose time limitations on students during the administration. Again, because of the severe handicaps that these children have, imposing time limitations would result in a significant underestimate of their skills and abilities.

Although the majority of achievement tests are unsuitable, criterion referenced achievement tests seem to be appropriate for use with the severely handicapped student. Criterion-referenced assessment gives specific information as to what skills a child has or has not achieved. On a criterion-referenced test, a person's performance is interpreted by comparing it to some specified behavioral criterion of proficiency. This is in direct contrast to norm-referenced tests where a student's performance is compared to that of all other students of his age and grade. By eliminating the unfair comparison between the handicapped student and his normal peers, the criterion-referenced tests offer much more educationally valuable information.

C. Rationale for Modification of Tests

Since most academic achievement tests would be inappropriate for the non-vocal, severely handicapped child, a search was conducted for tests that could be modified for use with this population. Test modification is an established and accepted procedure in the history of individual testing of the handicapped. By noting all modifications and considering them in the test score interpretations, valuable diagnostic information can be obtained without creating an entirely new test.

II. SELECTION OF TESTS

A. Test Criteria Established

The first step in the selection of tests to be included in the Baseline Diagnostic Inventory was to establish the criteria which the tests were to meet. In order to be suitable for the population of non-vocal, severely physically handicapped students and to satisfy the purpose of this study, it was felt that the tests selected should meet the following seven criteria. The criteria will be listed briefly and then discussed separately.

1. The tests should be either diagnostic or mastery achievement tests.
2. Test results should be interpretable in terms of specific behavioral objectives.
3. The tests should not require oral or written responses from the students.
4. The tests should cover as wide a range of academic levels as possible.
5. In test selection, the administration time required for the entire inventory should be considered, with a maximum of 2 days.
6. Classroom teachers should be able to administer and interpret all of the tests in the inventory without additional training.
7. The tests should have print and pictures that are large enough to be easily seen by students with mild visual handicaps.

The first criterion is that tests be either of the diagnostic or mastery type. Diagnostic and mastery tests are both types of achievement tests. All standardized achievement tests are designed to assess pupils' knowledge and skills at a particular point in time. Diagnostic tests "are designed to isolate specific strengths and weaknesses of an individual in some particular field of knowledge." (Meheens and Lehmann, 1973, p. 458).

A mastery test tries "to determine the extent to which pupils have mastered knowledge or skills considered to be fundamental to future learning." (Gronlund, 1971, p. 136). With a mastery test, a standard is arbitrarily set for the percentage of items that the child must answer correctly in order to have acquired or mastered that skill.

The second criterion is that the test results be interpreted in terms of specific behavioral objectives. Tests which are designed in this manner are known as criterion-referenced tests. It should be noted that "criterion-referenced" does not define a type of test in terms of function or content, but merely the manner in which the test scores are interpreted. With a criterion-referenced test, a person's performance is interpreted by "comparing it to some specified behavioral criterion of proficiency . . ." With this type of test interpretation, it is easy to see exactly what skills a child has and which ones he needs to learn.

Since the subjects under study will be both nonvocal and severely motorically involved, the third criterion is that the tests require no oral or written responses. Generally, this means that the tests would have to be in a multiple choice format so that the child could point to his responses.

The range of academic achievement of children in a comprehensive evaluation would be likely to run from preschool through high school. Therefore, the fourth criterion is that the tests survey the widest range of academic levels as possible. It would be preferable to have one test that covered the entire range of academic levels for a particular subject area so that comparisons could be easily made among the students.

A fifth criterion deals with the amount of administration time that the tests require. For the degree of motoric involvement that the subjects have, timed tests (or speed tests) would be thoroughly unrealistic. These subjects generally would spend a greater amount of time per item than the normal child, such that the test battery would take significantly longer to administer. In addition, these subjects expend a greater amount of physical effort on a task than the average child and need more frequent rest periods. The researcher should, however, keep a target total administration time in mind when developing the battery. The entire battery should be administrable within a maximum of two days. Since an inverse relationship generally exists between administration time and the amount of specific information obtained from the test, a time limitation was not set for each test.

The sixth criterion is that classroom teachers be able to administer and interpret the baseline inventory tests. Although the research staff may be administering the tests, the results would be given to the classroom teachers to help them in designing their instructional programs.

The final criterion is that the tests have print and picture size that would be clearly visible even for students with mild visual handicaps. Since a large percentage of cerebral palsied children have visual problems, this is felt to be an important consideration.

B. Search of the Literature

A Library search has been conducted in which general reference books, such as Buros Mental Measurement Yearbooks and specific texts on reading and mathematics diagnosis were consulted for an overview of available tests. Correspondence was conducted and personal consultations held with test publishers and with professors of educational measurements. Based on the recommendations from these sources, a number of tests have been reviewed in depth.

Achievement Batteries

The first test considered for a Baseline Inventory was a survey achievement test, the Peabody Individual Achievement Test (PIAT). A strong advantage of the PIAT is that it is designed so that it can easily be administered to the handicapped. Three of its five subtests - Reading Comprehension, Mathematics, and Spelling - are in multiple choice format for which pointing is the easiest response mode. The PIAT, however, was rejected since it did not meet the first two criteria. The PIAT is a wide-range screening measure and not a diagnostic or mastery achievement test. Secondly, test scores are completely norm-referenced rather than criterion-referenced. The PIAT would give some general indication of a child's strengths and weaknesses but nothing specific enough for the Baseline Inventory. The PIAT manual confirms this by stating, "It (PIAT) is not intended as a diagnostic instrument in a particular subject matter area, though it may play a part in a good diagnostic examination. Further, it is not intended as a precise measure of the exact level of an individual's achievements." (PIAT Manual, p. 56).

For the same reasons that the PIAT was rejected, other achievement survey batteries such as the Metropolitan Achievement Test, the Stanford Achievement Test and the California Achievement Tests were also rejected. These test batteries have the additional problem of being more difficult to administer to the severely handicapped child than the PIAT since items in these tests could not be responded to by pointing. Standardized achievement test batteries were therefore eliminated from consideration.

Reading Tests

The Baseline Inventory should assess three essential reading skill areas: word attack skills, word recognition and reading comprehension.

The following is a list of some popular reading diagnostic tests which proved to be inapplicable because of their emphasis on oral and/or written responses:

1. Durrell Analysis of Reading Difficulty.

2. Gates-McKillop Reading Diagnostic Test.

3. Monroe's Diagnostic Reading Examination.

4. Spache Diagnostic Reading Scales.

5. Botel Reading Inventory.

6. Woodcock Reading Mastery Test.

In order to find tests that do not require oral responses, it is necessary to go to group administered tests or to tests specifically designed to assess silent reading skills.

7. The Stanford Diagnostic Reading Test. (Harcourt, Brace and World, 1966) - is a group test which has some advantages. It is in multiple choice format, covering grades 2-8, and it assesses all three areas of reading skills - vocabulary, reading comprehension and word recognition. The test also has several disadvantages, however. Three of its subtests must be strictly timed in order for test scores to be compared to the norm group. All test results are norm-referenced, and test interpretation is in terms of grade equivalents, percentiles and stanines. In addition, test administration time is quite long (approximately 3 hours) for normal children and would be unrealistically long for NVPH children.

8. Science Research Associates has two kits for levels K-3 and 4-6 which are called SRA Diagnosis in Reading. Both kits contain a survey of reading skills. These survey tests are in multiple choice format for the most part, but there are also a number of questions which require written responses. The survey tests are quite short and only indicate general areas of strengths or weaknesses. Based upon these results, the student could be given a number of specific skills tests from the kit.

9. The Doren Diagnostic Reading Test of Word Recognition Skills (American Guidance Service, Inc., 1973) - provides an excellent set of word attack skill tests which could be used with the severely handicapped child with little modification. Subtests 1-3 and 5-9 are all multiple choice, including: Letter Recognition, Beginning Sounds, Whole Word Recognition, Speech Consonants, Ending Sounds, Blending, Rhyming and Vowels. Three subtests require written responses: Words Within Words, Discriminate Guessing and Spelling. Test results are summarized on a skill profile sheet for each child by plotting the number of incorrect responses per subtest. Each teacher may then set his/her own mastery level for that child.

10. The Wisconsin Tests of Reading Skill Development: Word Attack (Interpretive Scoring Systems, 1972) - are a series of criterion-referenced, mastery tests which cover all of the word attack skills that are normally taught (or at least introduced) in grades K-3. Each test covers a specific objective and mastery level is set at 80% correct. (See Appendix A for a list of all the objectives assessed.) Tests are available in two forms, P and Q. Time limits are not imposed but administration time is estimated at 5-15 minutes per subtest.

11. The Iowa Silent Reading Test (Harcourt, Brace and World, 1943) - has a number of limitations. It is essentially a comprehension test for grades 4-8 but several test items are outdated and misleading and test scores are norm-referenced.

12. Silent Reading Diagnostic Tests (Lyons and Carnahan, 1970) - are a set of 8 tests that evaluate word recognition and word attack skills. Each subtest covers one specific skill. The tests are normed for grades 2-7, and scores are interpreted in terms of grade equivalents, percentiles and stanines. The Word Recognition tests also offer Error Pattern scores and a separate interpretation of errors.

Arithmetic Tests

In the search for a diagnostic test of arithmetic, only 3 tests were reviewed in depth before one was chosen to be modified and included in the Baseline Inventory. There are two reasons why so few tests were reviewed. First, compared to the field of reading, there are very few diagnostic arithmetic tests available, and to our knowledge, none are directly useful for the assessment of non-vocal severely handicapped children. Secondly, after only 3 tests had been reviewed, a test was found which met most of the established criteria and which could easily be modified.

1. Diagnostic Tests and Self-Helps in Arithmetic (California Test Bureau, 1955) - proved to be unsuitable for a number of reasons. Written responses are required throughout the test. The arithmetic skills for grades 3-12 are assessed but not the skills taught in K-2. The screening tests cover only basic computational skills, omitting measures of mathematical concepts and problem solving.

2. The Stanford Diagnostic Arithmetic Test (Harcourt, Brace and World, 1966) - has two levels: grades 2-4 and 4-8. The tests are in multiple choice format and they cover the following skills. Level 1: concepts of numbers and numerals, computation and number facts. Level 2: concepts of numbers and numerals, computation with whole numbers, common fractions, decimal fractions and percents, and number facts. The

major disadvantage of the test is that test scores are completely norm-references.

3. Key Math Diagnostic Arithmetic Test (American Guidance Service, Inc., 1971) - is an individually administered test of arithmetic skills extending from K through 8. Test items are divided into 14 subtests which are organized into 3 major areas:

Content	Operations	Applications
A. Numeration	D. Addition	J. Word Problems
B. Fractions	E. Subtraction	K. Missing Elements
C. Geometry & Symbols	F. Multiplication	L. Money
	G. Division	M. Measurement
	H. Mental Computation	N. Time
	I. Numerical Reasoning	

Four levels of diagnostic information are provided:

> Level 1 - Total Test Performance. General placement information is provided through a grade equivalent score based on the student's total test performance.
>
> Level 2 - Area Performance. A general pattern is identified according to the student's performance in the 3 areas of content, operations, and applications.
>
> Level 3 - Subtest Performance. A profile depicts the student's relative performance in the 14 subtests.
>
> Level 4 - Item Performance. A description of the skill sampled on each item is given in the manual, providing a criterion-referenced scale.

The test is, therefore, both norm-referenced and criterion-referenced.

Within each subtest, the items are sequenced in order of difficulty. Test administration involves establishing a basal and a ceiling level for each subtest.

The major disadvantage of this test is that it requires oral and written responses for most of its items.

C. Tests Selected and Rationale

Based upon the review of available assessment measures, tests were selected that met as many of the previously established criteria as possible. If a test was not found in a given subject area which met all of the 7 criteria, one was selected which could most easily be modified. The following section will identify the tests that were selected and present a rationale for those decisions based upon the criteria that each test meets.

Reading Tests

The following 3 tests were chosen to cover the areas of word attack skills, word recognition and reading comprehension. Each test will be discussed in relation to how it met the previously established criteria and what modifications were necessary for administration.

Word Attack Skills. The Wisconsin Tests of Reading Skill Development: Word Attack - were chosen to assess this area since they best met the established criteria.

1. The Wisconsin Tests are mastery tests with each test measuring a separate skill or objective.
2. Each test is criterion-referenced, and mastery level is defined as 80% of the number of items per test correct.
3. All of the tests are multiple choice except "Right-to-Left Sequencing" and "Sight Word Vocabulary," both of which require oral responses from the student. Although the response alternatives are positioned so closely together that selecting a response by pointing would be impossible, the spacing problem seemed to be easily modifiable.
4. The skills tests are arranged in 4 levels, A-D, which are roughly equivalent to the traditional grade levels K-3. The manual explains, "Word Attack Skills are not given beyond level D because the essentials are introduced and taught to the average child by the end of the primary experience." (Guide: Word Attack, p. 3). Therefore, the levels are not limited to specific grades, but can be administered to students of any age or grade to determine whether or not they have mastered those skills.
5. The amount of time needed for test administration varies with each level and each subtest. Level A has 6 subtests and the manual estimates administration time at 1 hour, 20 min. For the 11 subtests of Level B, it would take approximately 2 hours; 17 subtests in Level C, 2 hours and 45 minutes; 5 subtests in Level D, 50 minutes. The manual also recommends that the testing be broken up into a couple of sessions over 2 or 3 days. if the child masters none or only one of

the Level B skills, for instance, he should be re-tested "down" using the Level A booklet. If he masters all or all but one of the Level B skills, he should be re-tested "up" using the Level D tests.

6. The tests are designed to be administered by a classroom teacher. Instructions and scoring are simple.
7. The print size throughout the tests is 1/16". Enlargement of the print size was viewed as a simple modification.

Word Recognition. The Silent Reading Diagnostic Tests 1 and 2 (Lyons and Carnahan, 1970) were selected as a measure of word recognition abilities. Test 1, "Words in Isolation" is composed of 54 items in which the child selects a word that describes a picture. Therefore, this test gives a measure of the child's recognition vocabulary. Test 2, "Words in Context" is composed of 30 items in which the child selects a word that logically completes a sentence. This test measures the child's ability to use context clues in word recognition. A measure of Word Recognition, in general, is computed by adding the scores from Tests 1 and 2 together.

1. The Silent Reading Tests are diagnostic tests in that they identify specific strengths and weaknesses in the area of word recognition. A comparison of the results from Test 1 with those of Test 2 would determine if a difference exists in the child's ability to recognize words in these two situations. When a child's score on "Words in Context" (2) is comparatively higher than his score on "Words in Isolation" (1), he either lacks a sight vocabulary or needs special assistance in word attack skills. A higher score on "Words in Isolation" than on "Words in Context" would indicate relatively ineffective use of context clues. The test provides more diagnostic information with an error pattern analysis on both tests 1 and 2. There are four types of possible errors in the Word Recognition tests: Initial, Middle, Ending and Orientation. If a child makes errors that have a consistent location within a word, this information would be significant in planning an instructional program for him.

2. This test is norm-referenced rather than criterion-referenced and it interprets scores in terms of grade equivalents, percentiles and stanines. No word recognition tests were found which did not use some type of norm-referenced scale for score interpretations. (Even the "Sight Word Vocabulary" test of the Wisconsin Tests of Reading Skill Development used Dolch word lists which are grouped in grade levels. Their objective for the Level B test is simply that, "the child recognizes first grade words from the adapted Dolch Sight Vocabulary List.") Since no criterion-referenced tests were available in this area, the Silent Reading Tests were selected on the basis that word recognition grade equivalency scores do have some utility in the classroom. Since almost all texts and children's books give an estimate of their appropriate reading grade level, which is somewhat standardized, this criterion was waived.
3. Tests 1 and 2 are both entirely in multiple choice format. Response alternatives, however, are positioned close together so that it would be difficult to indicate a response by pointing. This was seen as an easily modifiable problem.
4. The Word Recognition Tests are appropriate for students who are reading at levels from second to mid-seventh grade.
5. Each test has a time limit of 10 minutes. The manual states that this is enough time for almost all of the students to complete the test. Therefore, the tests are actually power tests rather than speed tests. Since Silent Reading Diagnostic Tests are given time limits which permit almost all of the students to complete the items, it was felt that they could be adapted to the severely physically handicapped child, by simply removing the time constraints, without invalidating the results.
6. The tests are specifically designed to be administered by a classroom teacher.
7. The print size is approximately 1/16" high and pictures vary in size from 1" to 1-1/2". Enlarging the size of the print and pictures was seen as an easy modification.

Reading Comprehension. The "Reading Comprehension" subtest of the Peabody Individual Achievement Test (American Guidance Service, Inc., 1970) was selected as a measure of this skill. The "Reading Comprehension" subtest contains 66 items, each of which consists of two pages. The first page contains a sentence that the student reads once silently. The second page, which is exposed to the student after he has read the passage, has four alternative illustrations on it. The student is asked to select the one which best represents the meaning of the sentence he has just read.

1. The Peabody Individual Achievement Test (PIAT) is an achievement survey battery, not a diagnostic nor a mastery test. However, in this skill area, it was felt that a general idea of a child's reading comprehension ability was acceptable enough. A more detailed test of comprehension would either span a much smaller range of academic levels or would take much longer to administer.
2. The PIAT, like the Silent Reading Diagnostic Tests, is norm-referenced rather than criterion-referenced. The same defense is used in this case as with the Word Recognition tests. No suitable tests were found using anything other than grade equivalency score interpretations, percentiles or stanines. A reading comprehension grade level score is used to determine what level of books a child could independently read and what level is appropriate for instruction.
3. The "Reading Comprehension" subtest is completely multiple choice, with the response alternatives arranged so that the student could point to his response.
4. This subtest is appropriate for students from the middle of first grade through grade 12.
5. The PIAT manual estimates that the entire test battery will take only 30-40 minutes to administer. This subtest contains less than one fifth of the total items in the battery so it would take approximately 6-8 minutes. There are no time limitations imposed.
6. No formal training is required to administer the PIAT; however, the PIAT manual recommends that the administrator be thoroughly familiar with the test and practice administering it before he/she gives it to a child. Therefore, any classroom teacher could administer it if he/she takes the time to familiarize himself/herself with it.

7. Print size is approximately 1/8" and pictures are generally 3" x 4" which seemed to be an acceptable size.

Arithmetic Skills

Key Math Diagnostic Arithmetic Test (American Guidance Service, Inc., 1971) was chosen for the area of arithmetic skills.

1. Key Math is a diagnostic test of arithmetic. It covers the 3 major areas in arithmetic: content, operations and application with a total of 14 subtests. Items are hierarchically arranged in order of difficulty. Four levels of diagnostic information are provided: Total Test Performance, Area Performance, Subtest Performance and Item Performance.

2. Key Math is both norm-referenced and criterion-referenced. With the total test score, a grade equivalent interpretation can be made. Each item has a specific objective listed in the manual and items are also grouped into instructional clusters in Appendix B of the manual.
3. The four operations subtests of addition, subtraction, multiplication and division require written responses from the students. The other 10 subtests require oral responses. This is the major disadvantage of the test for the non-vocal, handicapped child. It was decided, however, that multiple choice distractors could easily be created to adapt this test.
4. Key Math was designed to assess arithmetic skills from K through 8.
5. The test manual estimates that administration time should take approximately 30 min. No time limits are imposed.
6. Key Math may be administered by anyone since extensive training is not necessary. The manual recommends that the administrator be thoroughly familiar with the test before administering it to a child.
7. Print size is approximately 1/8" high for the most part and pictures seem to be especially clear and easy to see.

In summary, four tests were selected to be modified and included in the Baseline Diagnostic Inventory. The PIAT "Reading Comprehension" Test and the Silent Reading Diagnostic Word Recognition tests provide global information on the student's reading abilities while both the Wisconsin Word Attack tests and the Key Math test provide a great deal of specific information on skill achievement.

III. TEST MODIFICATIONS AND RATIONALE

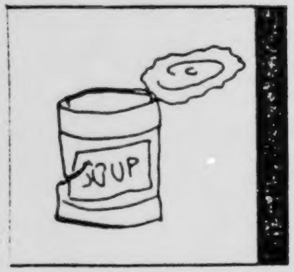
Since the tests that were selected did not meet all of the established criteria, it was necessary to make some modifications on each of them. The majority of modifications made affected the methods of test administration rather than the test content. Each test will be discussed separately, listing all of the modifications that were made.

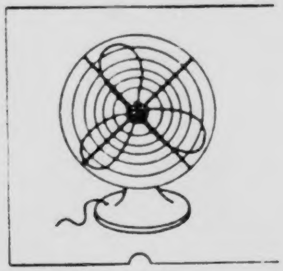
A. Wisconsin Tests of Reading Skill Development: Word Attack

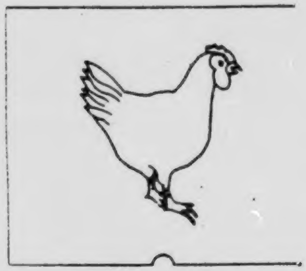
1. The two subtests which required extensive oral responses, "Sight Word Vocabulary" and "Left-to-Right Sequencing" were omitted from the battery.
2. For all of Level A, the response choices were separated by 1-1/4" in order to allow the subjects to point to their responses. The original test booklet was xeroxed and the xerox copies were used in the modified test. The test items were cut apart and each item was glued onto a separate 4" x 11" card, in order to allow enough room between the response choices. (See Figure 3 - Example of a Level A test item.)
3. For levels B through D, the print size was enlarged to 1/4" and the distance between response alternatives was increased to improve the test's readability. The distance between response alternatives depended upon the number of alternatives for that question.
4. The response alternatives in Levels B through D were numbered to allow students to select a response by pointing to its number on a number board. (See "Key Math Modification" for a description of the number board.)
5. Items for all levels were put onto cards. For Level A, the cards were 4" x 11". For Levels B-D, the cards were 5" x 7", 12" x 4-1/2" and 8-1/2" x 11". Placing each test item on a separate card should insure that the student is attending only to the item that is being administered.
6. All item cards were organized into loose-leaf notebooks to facilitate test administration. The notebook provides a convenient flip-page arrangement which can be set standing up on the desk in front of the student. This also permits the presentation of the stimulus materials at a better visual angle.

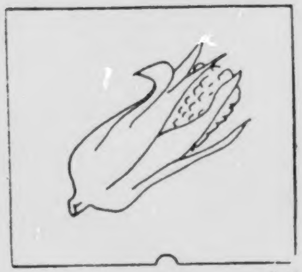
Figure 3

Example of a Level A Test Item









7. The Word Attack tests, which are designed as group administered tests, would be individually administered as part of the inventory.

B. Silent Reading Diagnostic Tests: "Words in Isolation", "Words in Context."

1. The time limits, 10 minutes for each test, which are given in the manual were eliminated. The manual states that these are power tests, not speed tests and that most children should finish within the time limits. Time constraints were removed in order to get a more accurate assessment of the subject's sight word vocabulary on the basis of the tests being power tests, rather than speed tests.
2. For the "Words in Isolation" subtest, the items were all photographically enlarged to twice their original size. This increased the print size to approximately 1/4" and doubled the size of the sketches. The items in "Words in Context" were also enlarged to a print size of 1/4". (See Figure 4 - Example from "Words in Isolation" and Figure 5 - Example from "Words in Context".
3. Response choices for both subtests were numbered so that subjects could select one by pointing to its number on a number board (see "Key Math" for a description of the number board).
4. All items, for both subtests, were placed on 5" x 7" cards and put into notebooks to facilitate in the test administration. The rationale for this was the same as it was for the Word Attack tests.
5. The Silent Reading Diagnostic Tests are designed as group administered tests; however, they will be individually administered as part of the inventory.

C. Key Math Diagnostic Arithmetic Test

1. Pointing was substituted for oral responses throughout the test.
2. A number board was constructed so that subjects could respond by pointing for items which required simple numeral responses. The board is a 10" x 14" x 3/8" piece of plywood with a sheet of white paper on the top surface. With rub-on type, the following characters were printed on the paper:

1 sailboat

2 selling

3 ails

4 snails

5 sailboth

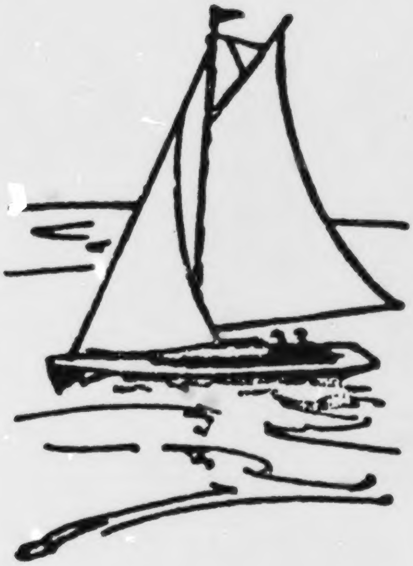


Fig. 4 : An item from "Words in Isolation".

He did not _____ his orders.

1. fullow 4. wollof

2. understem 5. understand

3. understrand

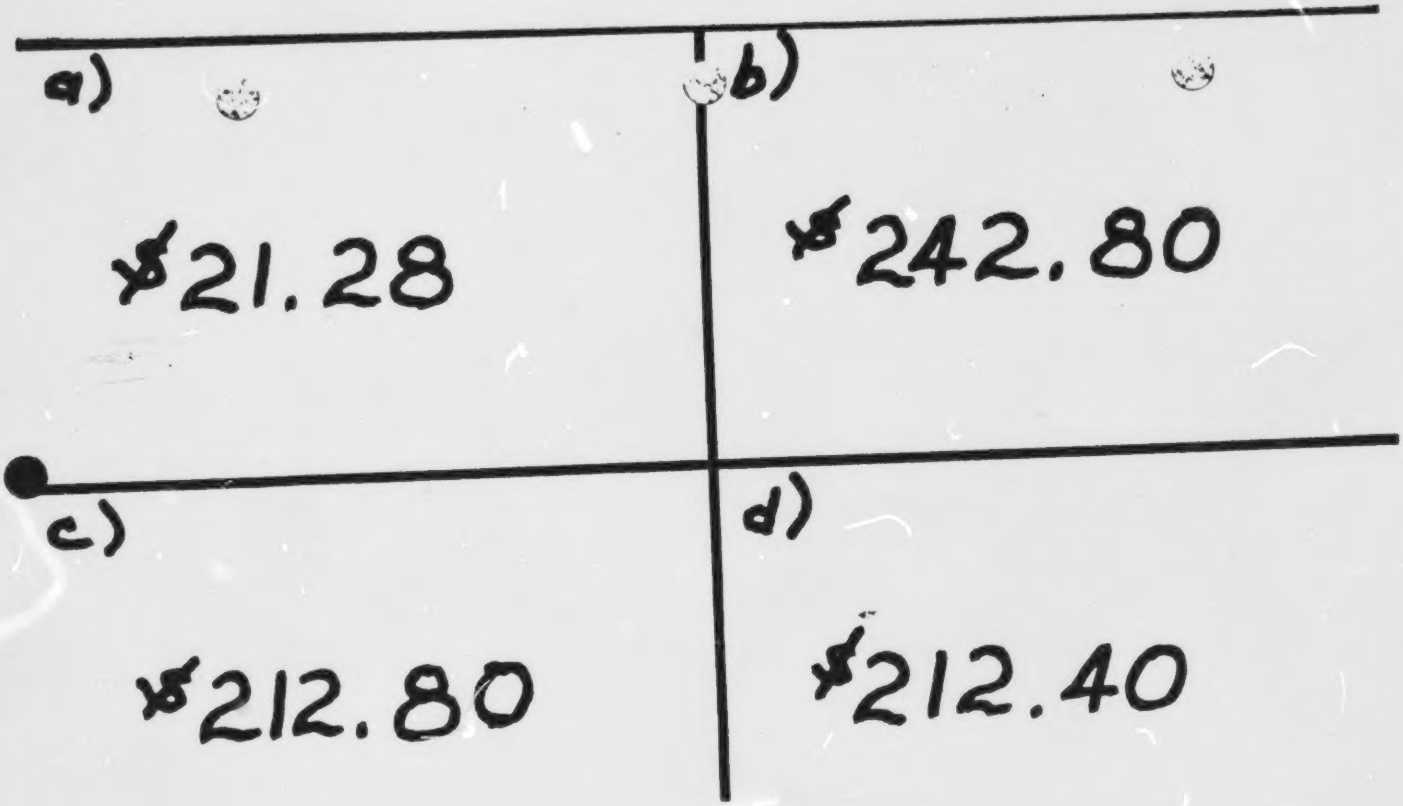
Fig. 5: An item from "Words in Context".

1, 2, 3, 4, 5, 6, 7, 8, 9, 0, $, ¢, 1/8, 1/5, 1/4, 1/3, 3/8, 2/5, 1/2, 5/8, 2/3, 3/4. The whole numbers are 3/4" high and the fractions are 1" high. The numerals are spaced approximately 1-1/2" apart. (See Figure 4 - A photo of the number board.)

3. Multiple choice distractors were created for 80 items. Distractors were created for all items which did not already have response alternatives in the test and which would be difficult to answer by pointing to numbers on the number board. Three distractors were created for each item. For example, item C-15 shows the problem 8 ÷ 4 = 2 with the division sign printed in red. The question is "What does the red sign mean?" The multiple choice alternatives in the modified version are: a) minus, b) times, c) percent, and d) divide. Distractors were also created for all of the computation problems that required more than a one numeral answer. (For one numeral answers, the students could respond using the number board.) For example, the computation problem for item F-9 is $30.40 x 7 and the modified test offers the alternatives shown in Fig. 6.

4. Eight test items were reworded to make them easier to respond to. The following is the list of questions and then the changes that were made:

A-19 - "Why is 40 the largest number?" to "Which is the larger number?"
A-20 - "Read this number rounded to the nearest thousand." to "What is this number rounded to the nearest thousand?"
A-21 - "Read this number rounded to the nearest hundred." to "What is this number rounded to the nearest hundred?"
A-23 - "Why is 7.5 the largest number?" to "Which is the largest number?"
B-5 - "What numeral is this?" to "Which of of these is the numeral three-eighths?"
L-1 - "Why does the middle box cost more than either of the others?" to "Which box will cost the most?"
L-10 - "Why is this the best if you need a lot of soup?" to "Which would be the best buy if you need a lot of soup?"



a) $21.28	b) $242.80
c) $212.80	d) $212.40

Fig. 6 Copy of Alternatives for Item F-9

M-6 - "If you were asked to measure the size of a large field by the inch, the yard, or the foot why would you you choose the yard?" to "If you were asked to measure the size of a field by the inch, the yard, or the foot, which would you choose?"

Each question was carefully rephrased so that the objective that was being tested remained the same. What was essentially changed was the mode of response. Rather than having the student name the fraction three-eighths, he is now asked to select 3/8 from among four alternatives. The student is still identifying the same numeral but in a different mode.

5. Subtest K (Missing Elements) was omitted in its entirety because all of the items within it require extensive oral responses, and they could not easily be modified to use another mode of response. If multiple choice distractors were created for these items, the subtest score would be confounded by the student's reading abilities.
   Missing Elements was not felt to be a critical skill in the battery. And, based on research by Goodstein, Kahn & Cawley at the University of Connecticut, the Missing Elements subtest appears to be one of the most inadequate in the Key Math Test due to its lack of adequate basal items.
6. The multiple choice responses were printed onto 5" x 7" cards (with print size of 1/4") and placed onto a notebook to facilitate the test administration.
7. All of the computation problems were enlarged to 5/8" for easier readability and printed on 5" x 7" cards also.

In summary, the Peabody Individual Achievement Test: Reading Recognition was suitable for use as it is and no modifications were necessary. For 80 items on the Key Math Diagnostic Arithmetic Test, multiple choice distractors were created and printed onto cards so that students could point to their responses. Some items were reworded to make them easier to respond to by pointing and one subtest was eliminated because it required extensive oral responses.

For both Wisconsin Tests of Reading Skill Development: Word Attack and Silent Reading Diagnostic Tests: Word Recognition, the major modifications made were: enlarging the print and picture size and arranging the items so that students could indicate their responses by pointing. The Word Attack and Word Recognition tests as well as the Key Math multiple choice items were printed onto cards and placed into an easel-kit notebook format.

IV. FIELD TESTING OF THE MODIFIED TESTS

In order to determine the value of the modified versions of the tests, it was necessary to administer them to a small sample of students who would be representative of a population which would be studied in a Comprehensive Evaluation program.

A. Objectives of the Field Testing

The objectives of this field testing were:

1. To discover problems which might arise in the test administrations so that they could be corrected before including them in a Baseline Diagnostic Inventory.
2. To estimate the amount of time that would be required for administration of the entire diagnostic inventory.

B. Methods

1. Subjects. Five non-vocal, severely physically handicapped students were selected to be subjects for the field tests. All five of the students were participants in the 1974-75 Field Evaluation of the Auto-Com.

The students ranged in age from 8-21 years of age. Three of the students attended public schools in self-contained classrooms for the multiply handicapped, one was in a residential hospital school and one was in a public high school resource special education classroom. See Table 7.

TABLE 7

Student	Age	Educational Environment
T.H.	14	Self-contained class for multiply handicapped.
C.C.	16	Self-contained class for multiply handicapped.
C.R.	8	Self-contained class for multiply handicapped.
M.M.	19	Residential hospital school.
D.C.	21	High school resource special education classroom.

2. Procedures. The modified Key Math Diagnostic Arithmetic Test was administered to all 5 students. Three students were given some of the modified Word Attack Skills Tests and two students took the modified Word Recognition Tests. All of these tests were administered during a regular school day. The test administrations took place either in a corner of the student's classroom or in a separate school room.

The PIAT Reading Comprehension subtests were given to all of the students as part of a battery of tests administered at the University Neurological and Rehabilitation Hospital. Since the PIAT Reading Comprehension test was being used in its original format, the Trace Center staff did not readminister this subtest to the students.

C. Results

1. Test Scores. The scores for all of the students given the modified tests are presented in Tables 8 and 9. Table 2 shows the results of the Word Attack Skill tests that were administered to 3 students. Each subtest assesses a separate skill. A skill is said to have been mastered if the student has 80% of those test items correct. Skills that have been mastered are designated by an asterisk.

No student received an entire level of tests due to time constraints. A few tests were selected at a level which seemed to be most appropriate for that student. Note: In the administration of the Baseline Inventory, a student would be retested with another level depending upon his performance on the tests given first. For example, if the student has mastered none or only one of the Level B skills, he would be retested "down" with Level A. If he has mastered all or all but one of the Level B skills, he would be retested "up" using Level C.

Table 9 shows the results from the administration of the modified Silent Reading Diagnostic Tests 1 and 2. Both tests were administered to student T.H. and Test 1 was given to student C.C. Grade equivalent scores are given for each subtest and a total Word Recognition score (Test 1 + Test 2) is also given. An error pattern is delineated for each of the tests to indicate the location(s) within words where the student most frequently makes his errors. Student T.H. shows a wide variation in types of errors and does not make a significant number of errors in one location. Student C.C., on the other hand, has comparatively greater problems with initial errors, i.e., at the beginning of words, than with any other type.

Table 10 shows the results of the Modified Key Math Test.

TABLE 8

Field Test Results of Modified Wisconsin Tests of Reading Skill Development: Word Attack

Student CC, Age 16

Skills - Level B	Raw Score	Total # of Test Items	Per Cent Correct	Mastered
3 - Beginning Consonant Sounds	17	20	85	*
4 - Ending consonant Sounds	17	20	85	*
5 - Consonant Blends	13	20	65	
6 - Rhyming Elements	8	20	40	
7 - Short Vowels	8	15	53	
8 - Consonant Digraphs	16	17	94	*

Student CR, Age 8

Skills - Level A	Raw Score	Total # of Test Items	Per Cent Correct	Mastered
1 - Rhyming Words	6	15	40	
2 - Rhyming Phrases	7	15	46	
Skills - Level B				
3 - Beginning Consonant Sounds	12	20	60	
4 - Ending Consonant Sounds	8	20	40	

Student TH, Age 14

Skills - Level C	Raw Score	Total # of Test Items	Per Cent Correct	Mastered
2 - Consonants and Their Variant Sounds	12	24	50	
3 - Consonant Blends	11	15	73	
4 - Long Vowel Sounds	26	30	86	*

*Mastery level here is defined as 80% of items per test correct.

TABLE 9

Field Test Results with Silent Reading Diagnostic Tests 1 & 2

Subject TH, Age 14

WORDS IN ISOLATION - TEST 1

Raw Score = 29
Total # of Test Items = 54
Grade Equivalent = 3.0

Error Pattern	
Initial	7
Middle	9
Ending	6
Orientation	3
Total Errors:	25

WORDS IN CONTEXT - TEST 2

Raw Score = 6
Total # of Test Items = 30
Grade Equivalent = 2.3

Error Pattern	
Initial	7
Middle	5
Ending	5
Orientation	7
Total Errors:	24

TOTAL OF TESTS 1 & 2
WORD RECOGNITION

Raw Score = 35
Total of Items Test 1 & 2 = 84
Grade Equivalent = 2.9

Error Pattern	
Initial	14
Middle	14
Ending	11
Orientation	10
Total Errors:	49

Subject CC, Age 16

WORDS IN ISOLATION - TEST 1

Raw Score = 20
Total # of Test Items = 54
Grade Equivalent = 2.3

Error Pattern	
Initial	14
Middle	7
Ending	8
Orientation	5
Total Errors:	34

TABLE 10

Field Test Results of the Modified Key Math Test

Subtest	Total No. of Objec-tives	S_{DC}		S_{WM}		S_{TH}		S_{CR}		S_{CC}	
		Total Correct	Objs. Missed	Total Correct	Objs. Missed	Total Correct	Objs. Missed	Total Correct	Objs. Missed	Total Correct	Objs. Missed
A - Numeration	24	24	--	24	--	14	#14,15 17-24	4	#2,6-24	19	#14,18 22-24
B - Fractions	11	8	#9,10,11	11	--	3	#4-10	--	#1-11	5	#6-10
C - Geometry & Symbols	20	18	#17,19	20	--	12	#7,13, 14,16-20	--	#1-20	16	#17-20
D - Addition	15	15	--	15	--	8	#7 10-15	2	#3-15	12	#12,14,15
E - Subtraction	14	14	--	14	--	6	#6 8-14	--	#1-14	9	#10-14
F - Multiplication	11	10	#11	10	#10	5	#6-11	--	#1-11	NA	NA
G - Division	10	9	#10	10	--	3	#4-10	--	#1-10	NA	NA
H - Mental Computations	10	10	--	10	--	2	#3-10	1	#2-10	10	--
I - Numerical Reasoning	12	11	#12	11	#12	7	#8-12	1	#2-12	9	#9,11,12
J - Word Problems	14	10	#11-14	10	#11-14	5	#6-14	--	#1-14	10	#11-14
L - Money	15	11	#10 13-15	13	#14,15	6	#6,8-15	--	#1-15	NA	NA
M - Measurement	27	20	#21-27	25	#25	11	#12-27	--	#1-27	NA	NA
N - Time	19	19	--	18	#19	14	#12 16-19	--	#1-19	NA	NA
RAW SCORE	202	180		191		96		8			
GRADE EQUIVALENT		7.5		8.7		3.1		0.2			

NA - Due to time limitations, these subtests were not administered

* - Since the entire test was not given to S_{CC}, a raw score and grade equivalent are not calculated.

2. Problems. Through the field testing procedures, several problems were discovered and remedied. The first problem was positioning the administrator in relation to the student. In administering the first two Word Attack tests to student C.R., the administrator was seated next to the student. C.R.'s classroom teacher noted that it is important for C.R. to be able to see the administrator's face in order to better discriminate the questions. This proved to be a valuable suggestion not only for administering other tests to C.R., but also to the rest of the students. Therefore, a procedure was established for the administrator to position himself at an angle in front of the student where the student can see the administrator's face during the test.

A second problem arose with the number of materials that the administrator had to handle during the tests, especially with Key Math. As the administrators became more familiar with the testing procedures, the problems lessened. However, one change was made that contributed significantly to lessening the confusion. The correct response for each item was written on the back of the item card. Since the test administrator is seated across from the student, he will see the correct answer as he flips to the next item. This is especially helpful for the Key Math test when the administrator must know if the child has established a basal or a ceiling.

For each child the positioning of the test materials may be laid out differently depending upon the student's visual ability and range of motion capabilities.

The third problem which arose was that of the test materials being dirtied or destroyed by the students. This was easily solved by covering all of the test materials with contact paper.

3. Administration Time Required. The amount of time that was required to administer each of the tests depended upon a number of factors: the amount of physical control the student had, the interest and attention span of the student, and the student's level of fatigue.

The average amount of time for the Word Attack test, given to 3 students, was approximately 15 minutes per test. This is about 5 minutes longer than the amount of time that the Wisconsin Tests Manual estimates. For the Silent Reading Diagnostic Tests, each test required approximately 25-30 minutes. The average testing time for the modified Key Math was 1 hour and 45 minutes with a range of times from 1 hour to 2½ hours, including rest periods.

D. Discussion

Generally, the results obtained from the modified tests were in agreement with other achievement test scores available and with informal teacher evaluations of the students' skills. For example, students D. C. and M. M. are both performing well in high school math programs, therefore it was expected that they would show a mastery of most of the elementary school curriculum. The teachers of both students C.C. and T.H. report that their students have serious word recognition problems which confirms the data from the Silent Reading Diagnostic Tests.

ADDENDUM B

SURVEY OF CRITICAL FACTORS INVOLVED IN EVALUATING COMMUNICATION AIDS

A Survey of Critical Factors In Evaluating Communication Aids

by

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December 1974

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I. INTRODUCTION

A. STATEMENT OF THE PROBLEM

Recent legislation directs that all exceptional children, no matter what the type or degree of their handicap, be provided with appropriate and effective educational programs. As a direct result of this legislation, handicapped children are being provided with educational opportunities which will enable them to become more active participants in school and vocational programs and thus to lead more productive and meaningful lives. Although most handicapped children will begin immediately to benefit from these new opportunities, there is a significant number of children for whom educational placement will result in frustration, both for themselves and for their teachers and parents. These children are those who are severely handicapped, i.e., non-ambulatory, non-vocal, non-pointing and non-manipulative. The non-vocal severely handicapped child who is unable to communicate effectively through writing, typing, signing or gesture will not be able to participate in most currently available educational programs. His inability to communicate and interact with his environment will have a devastating effect upon any potential benefit which may be derived from new educational opportunities. In order for these children to benefit maximally from educational and vocational programs, they must first be provided with an efficient, effective and unambiguous mode of communication.

Currently, there are a number of different techniques and aids which can augment the existing communication abilities of these children (Harris-Vanderheiden, Vanderheiden, 1976); however, only a few of these aids and techniques have been field tested with the population for whom they were designed. In addition, of those aids or techniques which have been field tested, only two evaluations have dealt with aspects of providing communication through augmentative modes other than physical evaluation of the features of the aids and/or the length of time needed to master the operation of the aid (Vanderheiden, Harris-Vanderheiden, 1976). As more becomes known about augmentative aids and techniques now available, field test information on different types of aids and techniques and their usefulness for different types of children will be imperative. Educators, clinicians and parents concerned with children's communication skills as prerequisities to effective educational development must be provided with information which will help them to choose aids and techniques which will maximize each child's potential and skill development.

Since educators, clinicians and parents will ultimately choose and apply various aids, it is important that information which they need in order to evaluate and implement programs utilizing the aids be included in field tests of the aids; therefore a survey of factors involved in evaluating communication aids has been developed and administered to those key persons involved in developing and/or utilizing communication aids.

B. PURPOSE/GOALS OF THE SURVEY

The survey has been administered and responded to by special educators, speech clinicians, rehabilitation engineers, occupational and physical therapists, educational researchers, educational administrators and parents of severely handicapped children. The primary purpose of the survey was to elicit these persons' opinions concerning critical factors to be included in field tests of communication aids and techniques designed to augment the existing communication abilities of non-vocal severely handicapped children. Special educators and speech clinicians were included, as they will be directly involved in implementing programs utilizing these aids; rehabilitation engineers were included, as they have played and will play a major role in the design and development of aids; educational researchers will become involved in field test programs; educational administrators will be involved in overseeing programs using aids and in purchasing aids for clinics and schools; occupational and physical therapists will be involved in preparing children for the use of aids and in interfacing children to aids; and parents will be directly involved in communicating with their children through the aids and in integrating the aids into daily family activities.

The information collected through this survey has been designed for distribution to instructional material developers, researchers working on the design and development of new aids, and educators/clinicians and parents who will be the ultimate field testers of the aids.

II. METHODS

A. SURVEY CONTENTS

The four page survey contained questions which elicited field reactions to various aspects of field testing aids and techniques, including:

1) the importance of field tests

2) information most desired from a field test

3) persons who should conduct field tests

4) types of research designs desired in field tests

5) most important reasons for field testing communication aids

6) questions that one would ask upon being introduced to a new communication aid or technique.

B. POPULATION SAMPLED

A total of 105 surveys was distributed and 70 were returned (66 percent of the original surveyed population). The composition of the population to whom the survey was sent and from whom responses were received is summarized in Table 1.

TABLE 1
DISTRIBUTION OF POPULATION SAMPLED

Population Sampled	% of original population	% of returned surveys
Special Educators	25	24
Speech Clinicians	22	22
Rehabilitation Engineers	22	22
Educational Researchers	9	10
Educational Administrators	12	11
Occupational and Physical Therapists	5	6
Parents	5	5
	N = 105	N = 70

III. RESULTS AND ANALYSIS OF SURVEY RESPONSES

A. IS FIELD TESTING IMPORTANT?

In response to the survey, 95 percent of the total population felt that evaluation of communication aids was very important. Survey respondents were also asked to choose and rank two of five aspects of field testing as of most interest. The survey question and responses follow:

If I were reading the evaluation of an aid, I would be most interested in an evaluation of: (Choose two and number in order of preference.)

_____ a) physical design of the aid

_____ b) interfacing the child to the aid

_____ c) the effect and value of the aid upon the child's educational, communicational and social skills and adjustment

_____ d) the amount of time it takes the child to learn how to operate the aid

_____ e) that aid and its effectiveness and applicability in relation to the applicability and effectiveness of other aids.

The overall population felt that evaluating the effect and value of the aid on educational and communication skill and social adjustment was most important. On an individual population basis, educators, engineers, educational administrators, parents and speech clinicians all agreed that this aspect would be of most interest. Educational researchers were split evenly between this aspect and evaluation of the aid under consideration in relation to other aids; and occupational and physical therapists were split evenly between the effect and value of the aid and interfacing the child to the aid (Table 2).

The second most important aspect of field testing of interest to the overall population was a split between interfacing the child to the aid, and the aid under consideration in relation to other aids. Educational researchers felt that the effect and value of the aid on educational and communication skill would be second in importance (Table 3).

B. WHO SHOULD CONDUCT FIELD TEST PROGRAMS?

When asked who should conduct field test programs (i.e., secure funding, analyze and report results), 91 percent of the total population felt that this was a job for an interdisciplinary team comprised of individuals representing each of the populations sampled (Table 4). The survey question and responses follow:

Who should conduct such evaluation programs (i.e., secure the funding and analyze and report results)?

_____ a) teachers

_____ b) speech clinicians

_____ c) rehabilitation engineers

_____ d) educational researchers

PERCENTAGE OF VOTES CAST BY SPECIAL INTEREST GROUPS FOR MOST IMPORTANT ASPECT OF FIELD TESTING

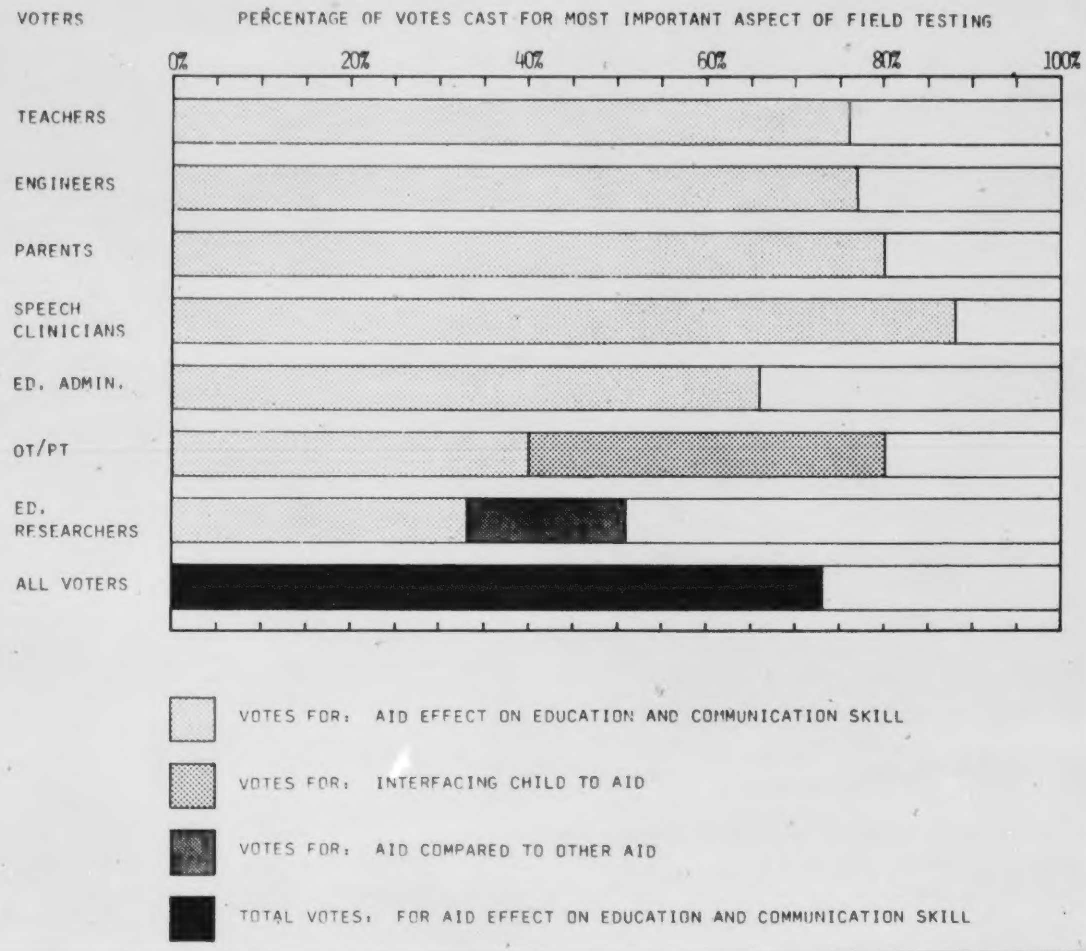
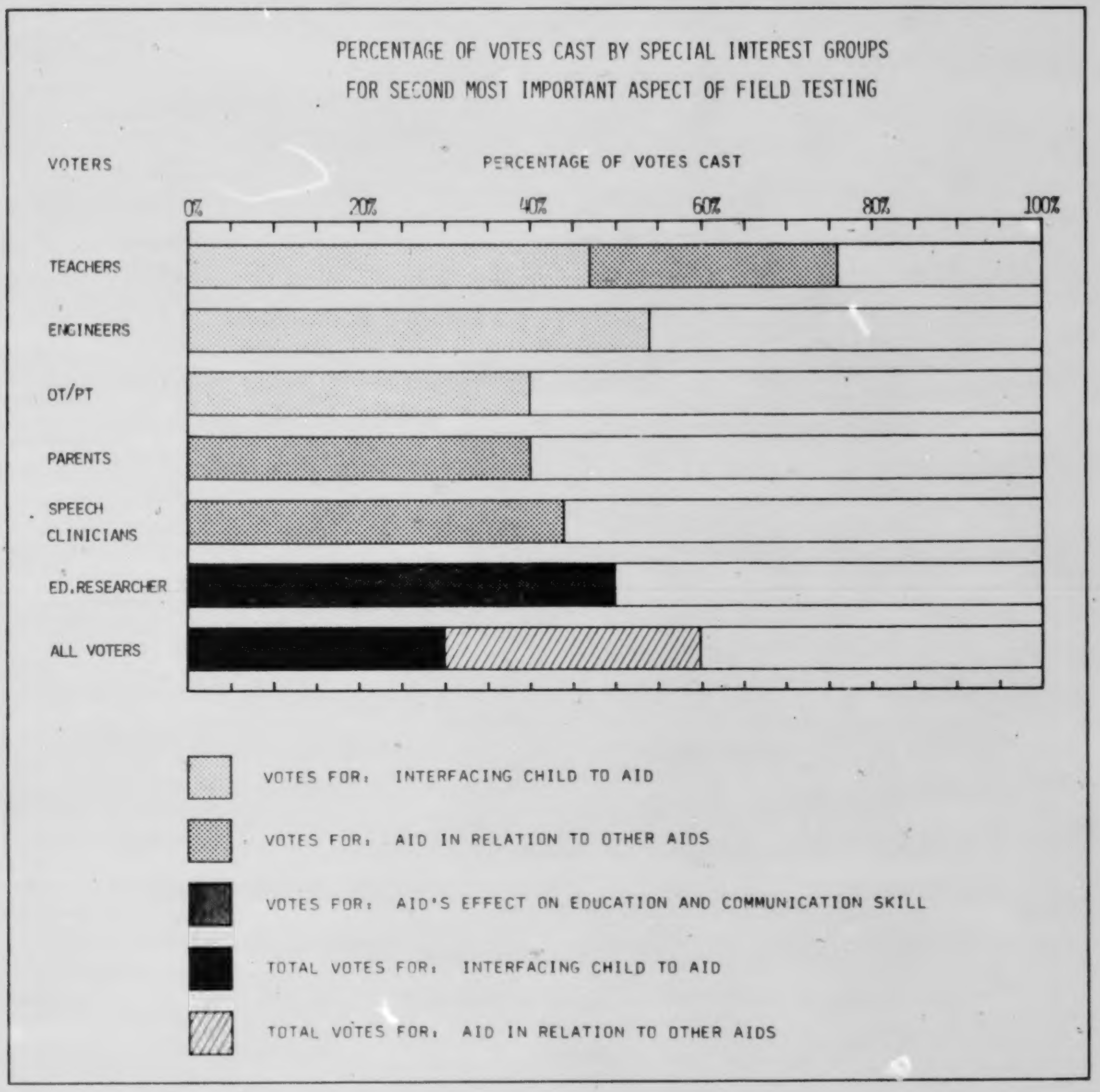
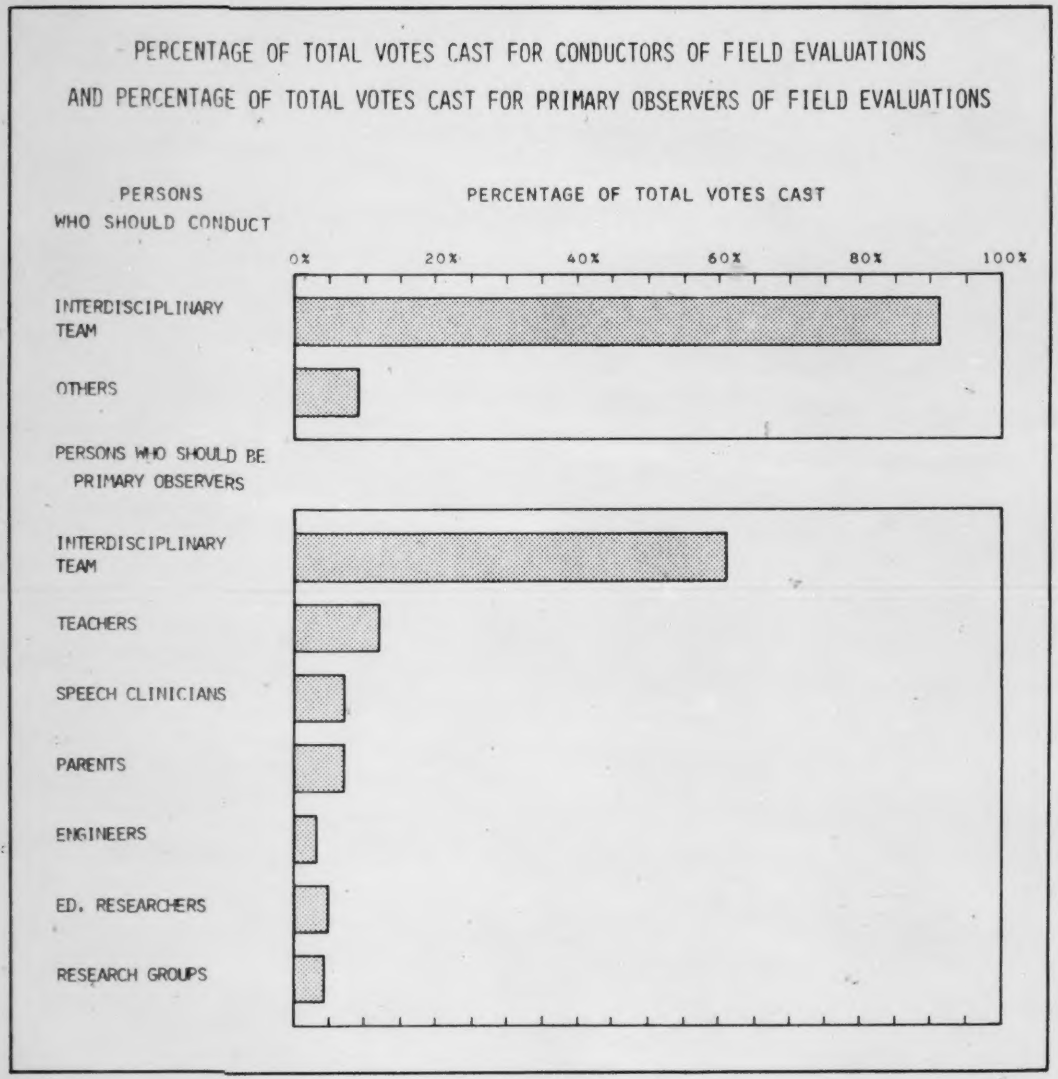


TABLE 2



PERCENTAGE OF VOTES CAST BY SPECIAL INTEREST GROUPS FOR SECOND MOST IMPORTANT ASPECT OF FIELD TESTING

TABLE 3



PERCENTAGE OF TOTAL VOTES CAST FOR CONDUCTORS OF FIELD EVALUATIONS AND PERCENTAGE OF TOTAL VOTES CAST FOR PRIMARY OBSERVERS OF FIELD EVALUATIONS

TABLE 4

_____ e) research groups working on the development of such aids

_____ f) an interdisciplinary team comprised of all of the above.

C. WHO SHOULD BE PRIMARY OBSERVERS AND DATA COLLECTORS?

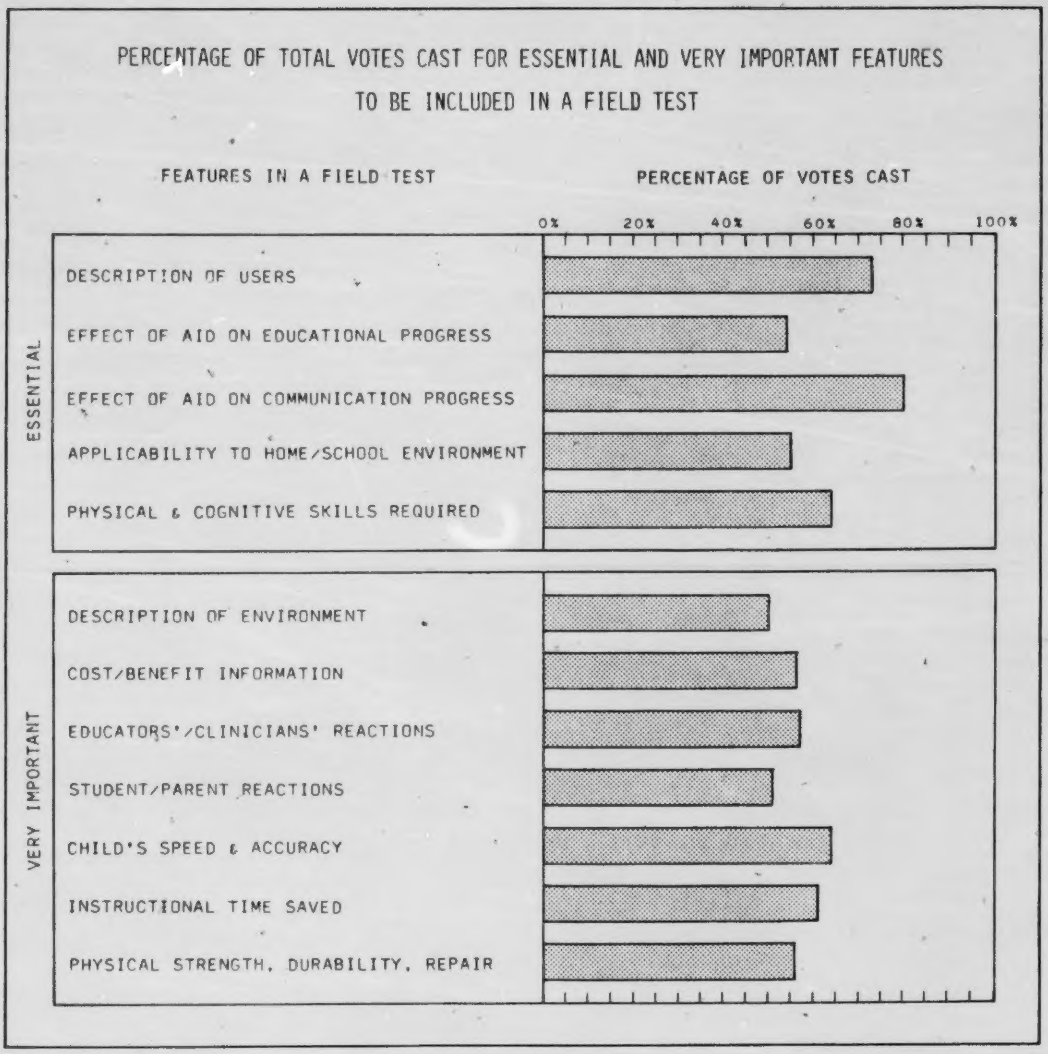
As for who should be the primary observers and data collectors for a field test, 61 percent of the total population responded that this was also a job for an interdisciplinary team; 39 percent of the total population chose either educators, speech clinicians or parents (or a combination of the above) as primary observers. The survey question and responses follow:

> Who should be the primary observers and data collectors for such an evaluation? (Check those appropriate.)
>
> _____ a) teachers
>
> _____ b) speech clinicians
>
> _____ c) parents
>
> _____ d) rehabilitation engineers
>
> _____ e) educational researchers
>
> _____ f) research groups working on the development of communication aids
>
> _____ g) an interdisciplinary team comprised of all of the above.

D. WHAT FEATURES ARE MOST IMPORTANT FOR INCLUSION IN A FIELD TEST?

Given 15 features or types of information which a field test could reveal about an aid, the survey respondents were asked to rank each feature as: 1) essential, 2) very important, or 3) interesting but not very important (Table 5). The survey question and responses follow:

> From your professional perspective, what information do you feel is most important regarding the evaluation of a communication aid? (If you were to design such an evaluation, or review one, what would you be looking for specifically?) Please read each response and then rank them according to:
>
> 1. Essential information
> 2. Very important
> 3. Would be interesting to include, but not very important.



PERCENTAGE OF TOTAL VOTES CAST FOR ESSENTIAL AND VERY IMPORTANT FEATURES TO BE INCLUDED IN A FIELD TEST

TABLE 5

_____ a) description of individuals using the aid, including physical and cognitive ability.

_____ b) description of environments and situations in which the aid was used

_____ c) information concerning the effect of the aid upon the individual's educational progress (i.e., effect upon learning rate, acquisition of skills, etc.)

_____ d) information concerning the effect of the aid upon the individual's communication skills (i.e., quantity and quality of communication, basic language skill development, etc.)

_____ e) information on the cost/benefits provided by use of the aid as opposed to use of other methods or techniques

_____ f) information on educators' and clinicians' reactions to the aid, and their use of the aid in classroom activities

_____ g) information on students' and parents' reactions to the aid

_____ h) information on the applicability of the aid to the classroom and home environments

_____ i) information on the physical and cognitive skills needed to use the aid effectively

_____ j) information on the amount of time required to use the aid effectively

_____ k) information on the individual's speed and accuracy of performance with the aid

_____ l) information on the effect of the aid upon quantity of instructional time saved through use of the aid

_____ m) information on reactions to the physical design of the aid, and the strength, durability and maintenance requirements

_____ n) information on the effect of the aid upon the individual's social and emotional adjustment

_____ o) information on the number and different types of ways to interface the individual to the aid

_____ p) other information. (Would you be specifically looking for something other than that mentioned here?)

Overall, those persons surveyed felt that information which was essential included:

1) description of individuals using the aid including physical and cognitive ability
2) information concerning the effect of the aid upon the individual's educational progress (i.e., effect upon learning rate, acquisition of skills, etc.)
3) information concerning the effect of the aid upon the individual's communication skills (i.e., quantity and quality of communication, basic language skill development, etc.)
4) information on the applicability of the aid to the classroom and home environments
5) information on the physical and cognitive skills needed to use the aid effectively.

Information which was felt to be very important included:

1) description of environments and situations in which the aid was used
2) information on the cost/benefits provided by use of the aid as opposed to use of other methods or techniques
3) information on educators' and clinicians' reactions to the aid, and their use of the aid in classroom activities
4) information on students' and parents' reactions to the aid
5) information on the individual's speed and accuracy of performance with the aid
6) information on reactions to the physical design of the aid and the strength, durability and maintenance requirements
7) information on the effect of the aid upon quantity of instructional time saved through use of the aid.

Information which was considered to be interesting but not very important included:

1) information on the amount of time required to use the aid effectively
2) information on the effect of the aid upon the individual's social and emotional adjustment

3) information on the number and different types of ways to interface the individual to the aid.

A complete profile of the responses, including individual population profiles, is presented in Table 6.

E. WHAT TYPE OF RESEARCH DESIGN SHOULD BE USED FOR FIELD TESTS OF THIS SORT?

Given the following choices, the persons surveyed were asked which type of study they would be most comfortable with.

> What type of study would you feel most comfortable reviewing, and/or would help you most? (Please circle one and explain why in 1 or 2 sentences.)
>
> _____ a)* a study with major emphasis upon quantitative information and statistical analysis of variables involved in use of the aid
>
> _____ b) a study with major emphasis upon qualitative systematic documentation of the use of the aid with different individuals, and teacher, clinician, child, and parent reactions to use of the aid.
>
> *Each study would contain some degree of both quantitative and qualitative information.

Seventy-seven percent of those surveyed responded that they would be most comfortable with a qualitative, case study type of evaluation design; 20 percent responded with, quantitative design; and three percent responded "both." When asked which type of study they felt would be most feasible for implementation in school systems, 89 percent responded with, qualitative case study; 10 percent with, quantitative; and one percent with, "both" (Table 7).

F. WHAT ARE THE MOST IMPORTANT REASONS FOR EVALUATING COMMUNICATION AIDS?

The respondents were asked to rank the most important reasons for evaluating communication aids, in the following manner:

> What do you feel are the most important reasons for evaluating communication aids for non-vocal physically handicapped (NVPH) children? (Number your top 3 choices.)
>
> _____ a) because anything new should be evaluated
>
> _____ b) to obtain an understanding of how communication aids can be used by NVPH children

TABLE 6: SUMMARY PROFILE OF INDIVIDUAL RATINGS OF FEATURES FOR INCLUSION IN EVALUATIONS

KEY: 1 = essential; 2 = very important; 3 = interesting, but not very important. CRITERION for rating the features per each respondent category was 50 percent (i.e., 50 percent or more of each of the respondent categories rated the feature as 1, 2, or 3). In cases of very close splits a double rating is indicated (e.g., 1-2).

SUBJECT	OVERALL	TEACHERS	ENGINEERS	SPEECH/ HEARING	EDUC. RESEARCH	EDUC. ADMIN.	OTHER	PARENTS
description of individuals using the aid, including physical and cognitive ability	1	1	1	1	1	1	1-2	1-2
description of environments and situations in which the aid was used	2	1-2	2	2	2	2	1	2
information concerning the effect of the aid upon the individual's educational progress (i.e., effect upon learning rate, acquisition of skills, etc.)	1	1-2	1	2	1	1	1	1
information concerning the effect of the aid upon the individual's communication skills (i.e., quantity and quality of communication, basic language skill development, etc.)	1	1	1	1	1	1	1	1

(Continued)

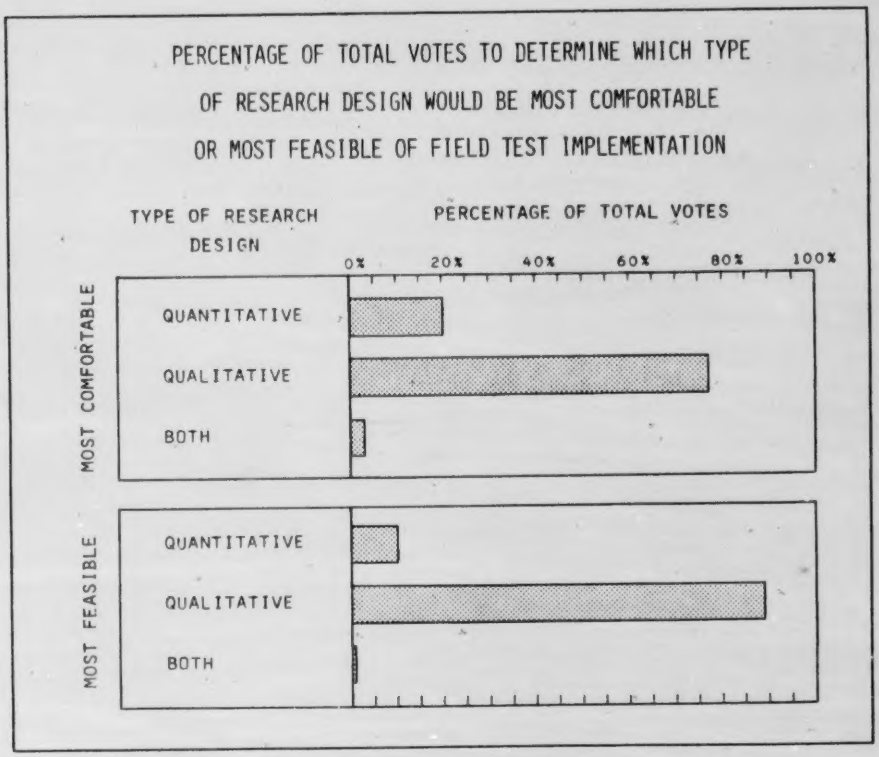
TABLE 6. SUMMARY PROFILE OF INDIVIDUAL RATINGS OF FEATURES FOR INCLUSION IN EVALUATIONS (Continued)

SUBJECT	OVERALL	TEACHERS	ENGINEERS	SPEECH/ HEARING	EDUC. RESEARCH	EDUC. ADMIN.	OTHER	PARENTS
information on the cost/ benefits provided by use of the aid as opposed to use of other methods or techniques.	2	1-2	2	2	2	3	2	2
information on educators' and clinicians' reactions to the aid, and their use of the aid in classroom activities	2	2	2	2	2	2-3	2	2
information on students' and parents' reactions to the aid	2	2	2	1-2	2	2-3	1	1-2
information on the applicability of the aid to classroom and home environments	1	1	2	1	2	1	1	1
information on the physical and cognitive skills needed to use the aid effectively	1	1	1	1	1	1	2	1
information on the amount of time required to use the aid effectively	1-2	2	2	2	2	1	2	3

(Continued)

TABLE 6. SUMMARY PROFILE OF INDIVIDUAL RATINGS OF FEATURES FOR INCLUSION IN EVALUATIONS (Continued)

SUBJECT	OVERALL	TEACHERS	ENGINEERS	SPEECH/ HEARING	EDUC. RESEARCH	EDUC. ADMIN.	OTHER	PARENTS
information on the individual's speed and accuracy of performance with the aid	2	2	2	2	2	2	2	2
information on the effect of the aid upon quantity of instructional time saved through use of the aid	2	2	2	2	2	2	2	2
information on reactions to the physical design of the aid, and the strength, durability and maintenance requirements	2	1-2	2	1	2	2	2	2
information on the effect of the aid upon the individual's social and emotional adjustment	1-2	1	2	2	2	1	2-3	2
information on the number and different types of ways to interface the individual to the aid	2	2	2	1	1	2	2	1



PERCENTAGE OF TOTAL VOTES TO DETERMINE WHICH TYPE OF RESEARCH DESIGN WOULD BE MOST COMFORTABLE OR MOST FEASIBLE OF FIELD TEST IMPLEMENTATION

TABLE 7

_____ c) to provide information which will allow me to obtain the most appropriate aid for a particular child (information which will allow comparative analyses of aids)

_____ d) to provide educational administrators and persons who finance aids for the handicapped with information on the cost/benefits of providing the severely handicapped child with a communication aid

_____ e) to provide information on the effect and value of communication aids as enhancing the educational skill and general development of the NVPH child

_____ f) to enhance the future development of aids by providing information on the advantages and disadvantages involved in using current aids

_____ g) other (Please explain briefly.)

Seventy-three percent of the respondents listed item c) "to provide information which will allow me to obtain the most appropriate aid for a particular child (information which will allow comparative analyses of aids)" as most important. Following that, the first or second most important reason selected by 70 percent of the participants was item (e) "to provide information on the effect and value of communication aids as enhancing the educational skill and general development of the NVPH child."

The top-ranked third choices for evaluating aids received 39 percent and 29 percent of the vote for third; respectively, these were items (f) "to enhance the future development of aids by providing information on the advantages and disadvantages involved in using current aids" and (d) "to provide educational administrators and persons who finance aids for the handicapped with information on the cost/benefits of providing the severely handicapped child with a communication aid." (See Table 8.)

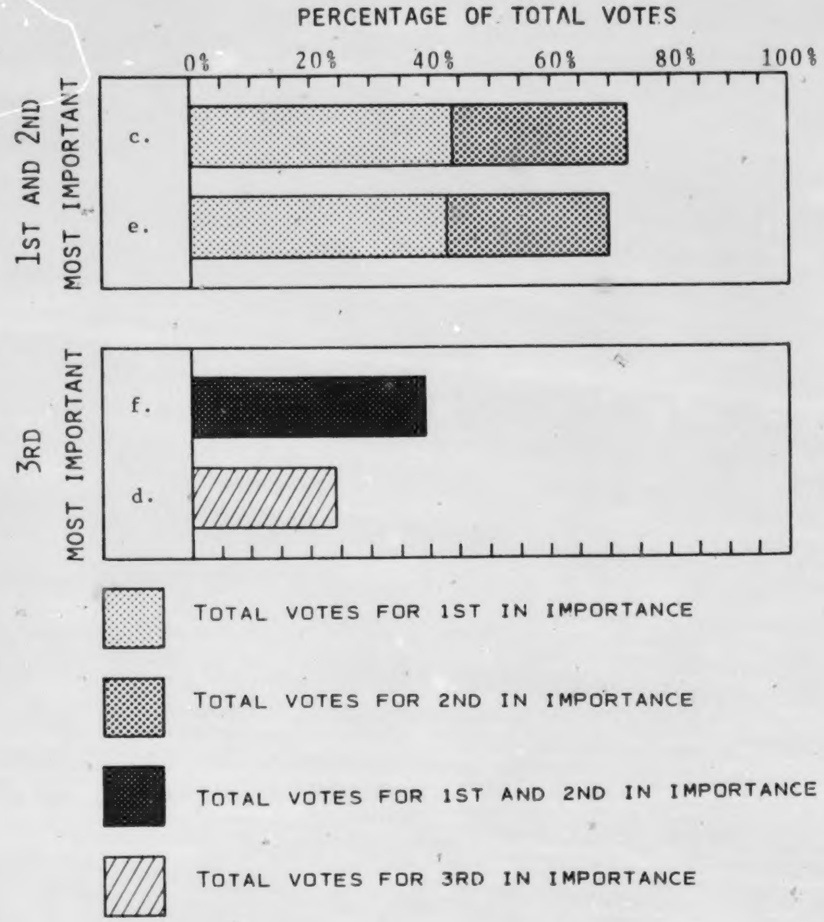
G. RESPONDENTS' CONCERNS ABOUT COMMUNICATION AIDS

In addition to asking participants to respond to and rank items or features, they were also asked to list those questions or concerns which they would voice before considering purchase or use of an aid with a non-vocal severely handicapped child.

In sum, the overriding concerns among all participants included:

1) cost
2) repair and maintenance
3) portability

PERCENTAGE OF TOTAL VOTES TO CHOOSE FIRST OR SECOND, AND THIRD MOST IMPORTANT REASONS FOR EVALUATING COMMUNICATION AIDS



c. To provide information which will allow me to obtain the most appropriate aid for a particular child (information which will allow comparative analyses of aids).

e. To provide information on the effect and value of communication aids as enhancing the educational skill and general development of the NVPH child.

f. To enhance the future development of aids by providing information on the advantages and disadvantages involved in using current aids.

d. To provide educational administrators and persons who finance aids for the handicapped with information on the cost/benefits of providing the severely handicapped child with a communication aid.

TABLE 8

4) versatility/adaptability
5) ease of transportation
6) availability
7) durability/reliability
8) ways of interfacing children/adults to the aid
9) past case study information (field test data) including:
    a) types of children the aid was developed for, and purposes for development
    b) who used the aid (successfully/unsuccessfully)
    c) in what situations was the aid most effective
    d) is the aid simple to set up and operate
10) physical and cognitive skills needed to use the aid effectively
11) length of time needed to learn to operate the aid
12) developmental adaptability and ability to modify the aid to different children and curriculum modes
13) applicability of the aid for severely retarded children
14) whether or not potential consumers are allowed a trial period
15) expected lifetime of the aid

H. SUMMARY OF CONCERNS

A summary of the concerns of the individual populations follows.

Teachers' Concerns:

1) does the aid foster independence?
2) what are other teachers' comments on the use of the aid?
3) what evidence is there of effect of the aid on educational progress?
4) how does it compare to other aids?
5) how much instruction time can it save?
6) is it a substitute for or a supplement to speech?
7) do vocalizations increase with use of the aid?
8) can a child do math problems with the aid?
9) what options are available with the aid? (output, etc.)
10) how much room is required for use of the aid?

Engineers' Concerns:

1) warranty and service information
2) ASCII interface to computers
3) input constraints
4) output capabilities
5) safety
6) ability to communicate simple and/or complex messages

Educational Researchers' Concerns:

1) how difficult is it for teachers to use the aid? (set up, training, etc.)
2) how can use of the aid be maximized?

Educational Administrators' Concerns:

1) training of staff needed (time, complexity)
2) limitations of aid
3) effectiveness of the aid in group versus 1:1 instruction
4) where the aid is being used now

Parents' Concerns:

1) how much help/assistance does child need in order to use the aid (i.e., independence)
2) is the aid adaptable to other aids?

Occupational and Physical Therapists' Concerns:

1) can the child set up the aid?
2) are there other aids in the area?
3) can it be combined with other aids?

Speech Clinicians' Concerns:

1) can the aid be used in class participation?
2) does it meet communication needs (express needs and feelings)?
3) what type of instruction is needed for use with the aid?
4) what form of printout is provided?
5) can the child correct errors?
6) is the speed (rate) of communication variable?
7) can the aid be used every day?
8) does it encourage communication?

IV. DISCUSSION/SUMMARY

In light of the above results, it appears that evaluation of communication aids is considered to be very important by special educators, rehabilitation engineers, speech clinicians, parents, occupational and physical therapists, educational researchers and educational administrators. Of primary interest to these persons is information on the effect and value of an aid upon severely handicapped children's educational, communication and social development. Second highest interests concern interfacing the child to the aid and comparative evaluation of particular aids and their effectiveness and applicability in relation to the applicability and effectiveness of other aids.

Respondents overwhelmingly chose interdisciplinary teams as persons who should be principally involved in conducting field evaluation programs. This included both implementing programs and analyzing results, as well as collecting data and observing children's use of the aid.

Educational researchers' frustrated attempts to conduct rigorous quantitative research designs (which are extremely difficult with the NVPH child) may not be necessary. Survey respondents almost unanimously agreed that qualitative case study information is more useful and more easily implemented in the classroom when evaluating the NVPH child's use of a communication aid. Essential information to be obtained from evaluative studies primarily concerned the effect and value of the aid on the child's educational and communication progress, the applicability of the aid to various environments and prerequisite skills needed to use the aid effectively. Other very important information was delineated as descriptive information on others' reactions to the aid (teachers, parents and children), the instructional time saved and cost/benefit of the aid, the effective operation of the aid by the child, and the physical durability and adaptability of the aid.

And finally, overall, survey respondents felt that evaluation of communication aids was most important in order to allow educators and parents to select the most appropriate aid for a child, and to provide general information on the effectiveness and value of a certain aid as it relates to educational and communication development. Secondary reasons included providing educational adminstrators with cost/benefit information and enhancing future development of aids through evaluation of those presently available.

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LANGUAGE STUDY

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PREPARATION OF INITIAL STUDIES

OF

LANGUAGE DEVELOPMENT PROCESSES IN

NON-VOCAL MOTOR IMPAIRED CHILDREN

-A PROGRESS REPORT-

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January 1976

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This is a progress report of an on-going research program
and should not be disseminated without the written consent of the author

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ABSTRACT

This report documents initial efforts being made by the Trace Center in researching language development processes of non-vocal motor impaired children. This report is composed of four sections that discuss rationale for exploration in this area, results of preliminary informal explorations, development of an improved data collection technique and an outline of a program for initiating formal research in this area. Major research issues discussed include collection of appropriate language corpuses which can serve as a basis for experimental probes and the development of appropriate data analysis techniques. Research issues and questions most relevant for immediate exploration concern: exploration into the non-vocal physically handicapped child's comprehension and production strategies, the effects of interactional and sensory/motor deficits on language development in the population and the effect of use of different types of communication aids upon the non-vocal physically handicapped child's expressive output.

INTRODUCTION

The inability of the non-vocal severely physically handicapped (NVPH) child to communicate has severely limited his ability to interact with other people and with his environment. It is generally believed that this lack of interaction negatively affects the NVPH child's personal and educational development. His development on the formal education level is limited by his inability to participate in classroom activity (i.e., he cannot communicate either through speech, gesture or prose). Such a limitation prevents his completing independent work, written tests or performing basic manipulative tasks, and in turn adversely affects his motivation and the teacher's ability to evaluate his cognitive abilities and needs.

For the NVPH child of normal or above normal intelligence, the effect of a communication isolation on his personal and educational development is devastating; for the NVPH child of below normal intelligence, the effect of a communication isolation on his personal and educational development is severely retarding.

The Problem

Educational programs for NVPH children must be instituted in public education systems. The first step toward providing meaningful and beneficial educational programs for these children is to develop a means with which the child can communicate effectively, such as a communication aid. Much work has already been done in this area and much more is still necessary. However, at present communication aids are available to facilitate the communication of NVPH individuals. (For more information in this area see Non-Vocal Communcation Techniques and Aids for the Severely Physically Handicapped, Gregg C. Vanderheiden and Kate Grilley,eds.)

The second step is to develop effective communication skills programs for NVPH children in the public schools. At present, investigators attempting to develop effective communication skill programs for this population are faced with lack of research in this critical area. There have been no systematic studies on language development processes in this population primarily due to problems involved in collecting appropriate data and production syntax from non-vocal, non-writing, non-manipulative children.

Thus, most attempts to develop communication programs have primarily relied upon the assumption that normal language acquisition data can apply to the NVPH child (e.g.,that the processes and sequences of linguistic maturation evidenced in a normal vocal child can represent the linguistic maturation of a non-vocal non-writing child). However, recent research has revealed that there may be qualitative and/or quantitative differences between processes involved in linguistic maturation of the normal child and that of other populations (e.g., NVPH children) (Yoder and Miller, 1972,Miller 1976)

In light of this, thorough investigation is needed before teachers and clinicians can adopt Normal Language Acquisition (NLA) as a basis for the development of communication intervention programs for the NVPH child as well as a model for the development of language in all children.

PAST WORK AND RECENT ADVANCES IN THIS AREA

Most of the research which has investigated communication and language function in NVPH children has been cursory and speculative. This is due to lack of data for analysis and a reliance upon visual observation of the child's communicative interaction. In addition, the bulk of this research, which deals with speech and articulation problems of the cerebral palsied child, is very outdated (Christman, 1954; Palmer, 1954; Bosly, 1954; Feallock, 1958; and Mecham, 1954).

In the past, in order to collect data, children's teachers and/or clinicians have had to manually transcribe utterances as they were pointed out on a communication board of some sort. Besides being laborious and time consuming, collecting data in this manner is not reliable. The teacher may anticipate words that the child is producing and finish them for him; thus, not allowing a representative view of what the child can do. Secondly, the child may not produce utterances which appropriately reflect his competency due to time constraints and pressure to complete thoughts.

Research investigating language development of handicapped children as it approximates or varies from language development of the normal vocal child has dealt with two major handicapped populations: mentally retarded children and hearing impaired children. Investigations of the linguistic/conceptual development of these children have centered around the children's comprehension and production abilities.

Research into these and other linguistic and cognitive areas in mentally retarded and hearing impaired children has allowed researchers to gain insight into developmental variables of populations whose major deficits involve processing or input. A very necessary area of research at this time involves investigation of similar processes in handicapped children whose major deficit is output (production ability)(Table 1).

Some research issues and areas of exploration into language development processes in NVPH children have been summarized in Table 2. Exploration of issues such as these will allow researchers both to gain insight into developmental processes of an unexplored population and to provide comparative information for studies conducted thus far on other populations.

With recent advances in the development of communication aids, NVPH children can now be provided with effective modes of communication which allow them to express their thoughts in an unambiguous manner and to construct their expression without the need for monitoring, translation and interpretation by others. These aids will allow researchers to obtain systematic reliable information on production abilities of children who may or may not have acquired reading and spelling skills.

TABLE 1

Summary of Current Research Findings

Normal, Vocal Child	Mentally Retarded Child	Hearing Impaired Child	Non-Vocal Physically Handicapped Child
Extensive exploration into the child's linguistic and conceptual development. Research has explored: -syntactic development -semantic development -conceptual development -mother-child and environmental interaction -development of extra linguistic variables (memory, perception, etc.)	Research has focused on comparing the mentally retarded child's linguistic and conceptual development to that of the normal vocal child. The same areas are under exploration. Overall results thus far indicate that MR children develop linguistically and cognitively similar to the normal vocal child but at a slower rate. (Yoder and Miller, 1972; Miller, 1975)	Research is focusing on studying the hearing impaired child's acquisition and development of linguistic and cognitive variables and comparison of findings to the normal vocal child. Overall results are indicating the HI children are more advanced conceptually than linguistically and the comprehension and production abilities are similar in level of development. (Chapman, personal communication, 1975)	No major research thus far due to methodological problems and lack of appropriate output mechanism. POSTULATE: That NVPH children develop linguistic system expressly through a comprehension mode and, when provided with an appropriate output mechanism, "transfer" this knowledge to a production mode. Comprehension and conceptual development similar with lag in production.
No Major Deficit	Major Deficit: Processing	Major Deficit: Input	Major Deficit: Output

TABLE 2

Major Issues and Areas of Exploration

1. How does the non-vocal severely handicapped child acquire a linguistic system?

    - What are the roles of comprehension and production?

    - What is the effect of intact input system and non-intact output system?

2. How does the NVPH child acquire and develop a conceptual system (as specifically related to language learning)?

    - What is the role of sensory-motor development on the language development of severely motor impaired children?

    - How similar or concurrent are the developing linguistic and conceptual systems in this population?

3. What is the role of mother-child and environmental interaction on the NVPH linguistic and communication strategies?

    - What type of linguistic input is provided to the child and how does this vary over time as the child is unable to communicate?

    - What is the role of play and imitative activity in the NVPH child's interaction and how is this engaged in?

4. What is the role/effect of the type of communication aid used upon expressive production and conceptual development?

5. What is the role/effect of the use of different types of vocabulary systems upon expressive production?

OBJECTIVES

The objective of our study was to begin initial exploration into the developmental language patterns of non-vocal physically handicapped adolescents. The study focused on three questions:

1) How does the NVPH child develop language and how might this be related to the development of language processes evidenced in the normal vocal child?

2) What vocabulary elements or words are used by the NVPH child or adolescent who is: a) learning to communicate or b) provided with a more effective means of communication after having had a manual communication board for some time?

3) How can a communication aid (such as the Autocom) enable an educator to better assess the NVPH child's linguistic ability and performance?

PROCEDURES

Communication Aid Used

The communication aid used by the students in this study was the Autocom, a portable aid developed by the Trace Center at the University of Wisconsin. The Autocom is a direct selection aid (i.e., one which the user operates by pointing to individual elements or words in order to construct thoughts or sentences). Although operated much like a teacher or parent fabricated language board, the Autocom differs in that a translator or second person need not be present to write down the user's message. Instead, the board monitors the child's pointing movements automatically and prints his message on a TV screen or small strip printer mounted inside the board. (For detailed information on operation and use of the Autocom, see Appendix A.)

The Autocom was chosen for use in this study because it was portable (could go with the child wherever he went); it offered the user the ability to print messages out on a highly visible, correctable display (the TV); and it allowed researchers to collect language samples via printout on the strip printer (see Figures 1-4).

Subjects

Three NVPH adolescents participated in this study. S_{LS}, a 14-year old male, had no oral communication skill and, prior to the Auto-Com, he used an alphabet/word board for communication. S_{CC} was also a 14-year old male and was the most severely handicapped student in the study. Prior to use of the Autocom, his communication consisted of a yes/no response to questions. S_{DC} was a 19-year old female - the most advanced academically. She had been using a language board (alphabet and words) prior to use of the Autocom (see Table 3).

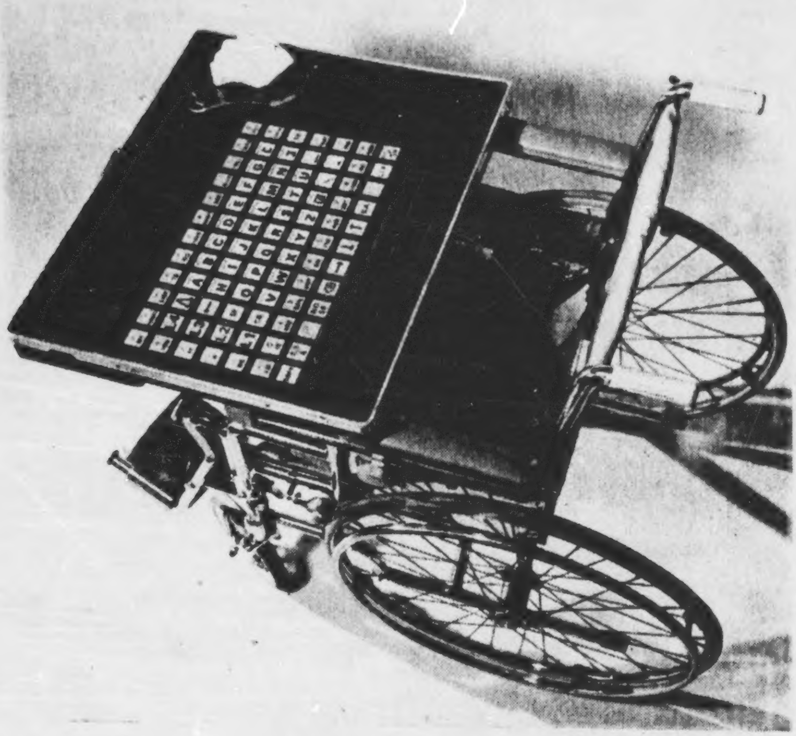

Fig. 1. Portable Auto-Com on Wheelchair

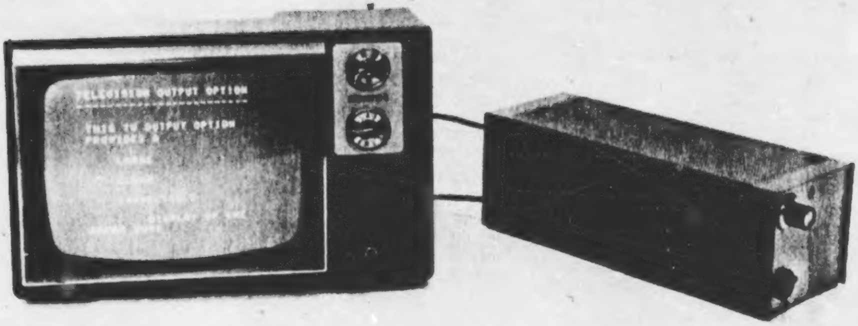
TELEVISION OUTPUT OPTION
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Fig. 2. TV Display Output of Portable Auto-Com

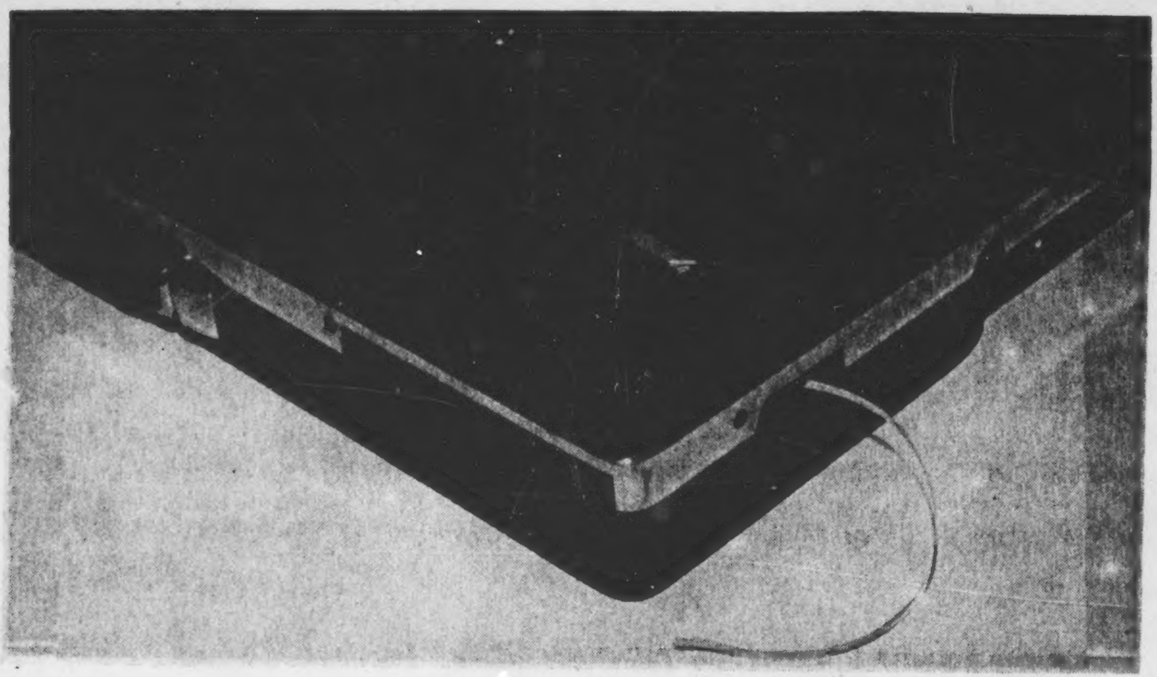


Fig. 3. Closeup of the Auto-Com Strip Printer

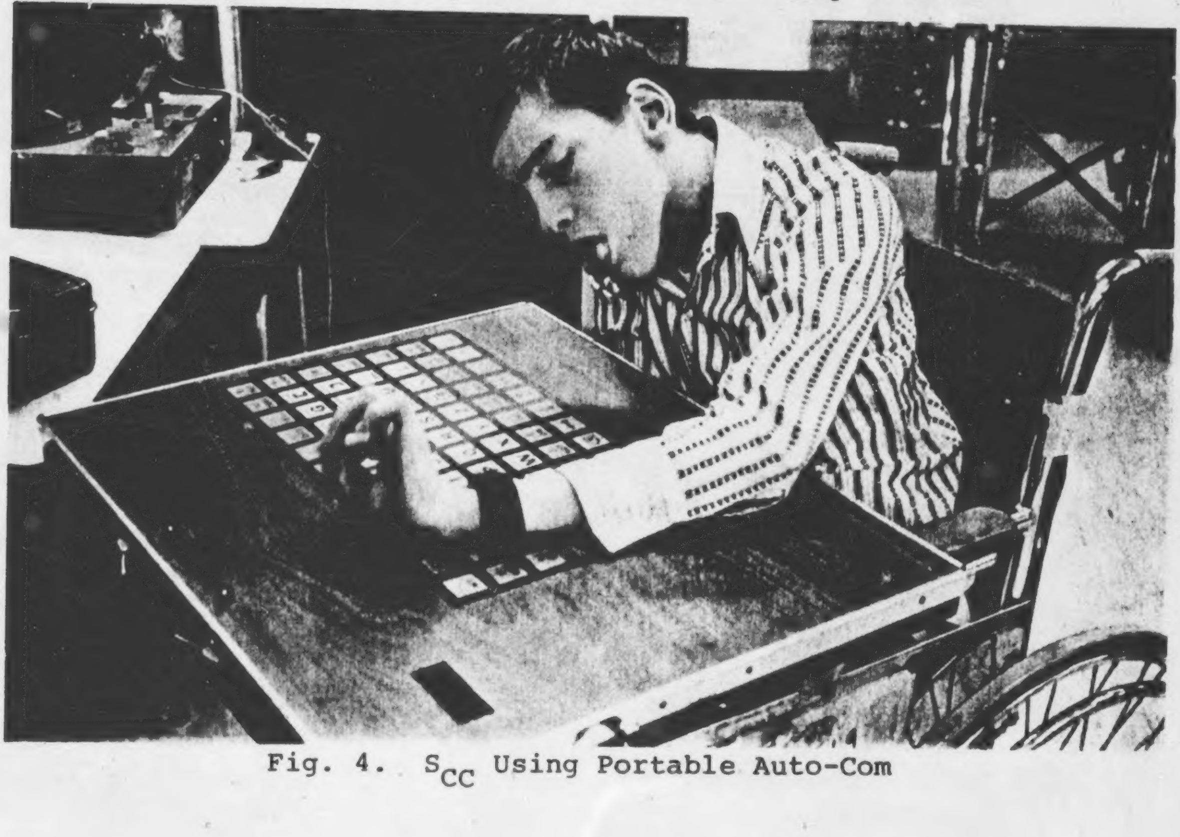


Fig. 4. S_{CC} Using Portable Auto-Com

TABLE 3

Subject Description

Subject	Age as of 9/73	Sex	Neurological* Description	Previous Communication Method (Prior to Autocom)	Date Receiving Autocom)
S_{DC}	19	F	Primarily athetoid, some spasticity on left side, quadraplegic	Language board, gestures with eyes and pointing	4/73
S_{CC}	14	M	Athetoid, quadraplegic Wristcock	Gestures (tried typewriter, but could not use)	12/74
S_{LS}	14	M	Athetoid, quadraplegic	Letter board, gestures	3/72

*Provided through a neurological and neuropsychological evaluation conducted by Dr. Raymond Chun and Dr. Charles Matthews, University Hospitals, Madison, Wisconsin.

Data Collection

In late April 1974, each of the students was administered a battery of language tests and conceptual development tests. These tests included: Assessment of Children's Language Comprehension (ACLA), the Miller-Yoder test of grammatical comprehension (MY), and the Boehm Test of Basic Concepts (BOEHM). In addition to these formal assessment measures, a language sample of approximately 50 utterances was obtained and analyzed. Throughout the evaluation period of five months (May-September 1974), data used in the study was collected through the following procedures:

1) A permanent record of all of the subjects' expressive output was obtained from the thermal print tape on the Autocom.

2) Daily five minute language samples and accompanying information pertaining to the educational and communicative environment at the time of the sample were obtained.

3) Information was gathered through teacher questionnaires, forms and interviews.

4) Formal and informal assessment measures were administered.

1) Permanent Recorded Output

All of the language samples used in this study were obtained from the thermal tape output of the Autocom. As the student printed out his message on the Autocom, it was permanently recorded on a small strip of thermal (heat sensitive) tape which was ejected out of the side of the board. The tape was approximately 1/4" wide and a taped message would appear like the following:

/DEAR MOM: HOW ARE YOU/

Tapes were collected for each day the child used the Autocom, and these consisted of successive utterances. Personal messages were excluded from our data gathering. Language samples were separated on the tape by a pen mark to clarify the end of one message and the beginning of another.

| THE BOOK | I WANT TO GO KMART WITH YOU | | I WANT |

↑ pen mark (indicating the end of 5-minute writing sample)

↑ personal message deleted

Permanent recorded output obtained from the tapes was used in the following analyses:

1) Vocabulary usage and word frequency studies
2) Developmental Sentence Scoring (DDS)
3) Analysis of sentence complexity other than that measured through DSS
4) Analysis of spelling, word order, word addition, and deletion of errors and letter and word reversals.
5) Analysis of the child's expressive language ability.

2) Daily Five-Minute Language Samples

In addition to collection of the recorded communications of each child for the day, the students' teachers were asked to collect two five-minute language samples per day. These timed samples were marked with hash marks on the thermal print tape, or written out on a questionnaire form. Accompanying each language sample, teachers were asked to include written information such as the following:

1) time of day
2) task or assignment the child was working on
3) whether or not the child was engaged in conversation
4) whether the child was working by himself, with one other person or in a group
5) additional notes and/or interpretation of the child's message

These five-minute language samples and accompanying information were used in the following analysis:

1) determination of the type of communication engaged in by the child
2) vocabulary usage and word frequency
3) language structure and development

3) Teacher Questionnaires, Forms and Interviews

Teachers completed general questionnaires and taped interviews which helped to provide information as to how well the child was communicating in the classroom; how he was using the Autocom and how well he was using it; what educational skills the child was participating in; and general background information necessary in order to give the researcher an idea of the educational, social and communication environment of the child. This data was used mostly for informational purposes in our study and helped the researcher become better acquainted with each subject.

4) Formal and Informal Assessment Measures

Assessment measurements used and rationale for the inclusion of each are summarized as follows:

a) Miller-Yoder Test of Grammatical Comprehension (MY)

The MY test is a picture selection test for measuring children's grammatical comprehension. The test consists of 84 sentences forming 42 sentence pairs with the following basic grammatical forms tested: 1) active; 2) preposition; 3) possessive; 4) negative/affirmative statements; 5) pronouns, object and subject; 6) singular/plural noun and verb; 7) verb inflections; 8) modification, object and subject; 9) modification, object and subject; 10) passive reversible; and 11) reflexivization.

This test was included as an assessment procedure because it measures grammatical and syntactical comprehension. Through it we were able to obtain an idea of the child's level of receptive language ability; his level of language comprehension; and his ability to identify, discriminate and match appropriate pictures to a particular sentence.

In addition, this test lent itself very well to adaptation with the NVPH child. Each sentence is represented by a clear black-on-white line drawing. The test consists of 42 plates with four pictures appearing on each plate. The pictures are large enough that even a severely motorically involved child can point to them. Most importantly, the test does not require a vocal response from the child.

b) Assessment of Children's Language Comprehension (ACL)

The ACLC test developed by Foster, Giddam and Stark assesses the child's language comprehension through a "critical elements index." The child is required to discriminate pictures given from one to four "critical elements." Example:

one critical element	shoe
two critical elements	horse standing
three critical elements	ball under the table
four critical elements	happy little girl jumping

This test was included as an assessment procedure because it measured aspects of language comprehension not covered by the MY test (such as vocabulary, and ability to identify, discriminate and respond to sentences presented with progressive difficulty).

In addition, the test was adapted to the NVPH child; it required no vocal response and pictures were spaced so as to allow a pointing response from even the most severely handicapped child.

c) Boehm Test of Basic Concepts (BOEHM)

The BOEHM test assesses the child's knowledge of concepts such as: top, through, away from, next to, inside, some, not, many, never, always, same, different, etc. The test administrator reads a sentence aloud to the child and the child points to the picture which describes the concept involved. Example:

T: The ball is on top of the box

C: Points to the picture depicting the ball on top of the box

This test, although designed for a much younger population than the subjects involved, was chosen for inclusion as an assessment procedure because it assessed basic concepts which are usually developed while the child is acquiring and developing language skills. It also lent itself well to adaptation to the NVPH child as it required no vocal response and was set up so as to allow pointing responses from even the most severely motorically involved subject.

Overall, these particular formal assessment measures were chosen because of their ability to assess the NVPH child's language comprehension and basic conceptual skills. These particular tests were chosen as appropriate (according to level of difficulty), for assessing the subjects' linguistic ability based upon teacher and parent feedback.

Procedures utilized in collection of data and application of information obtained are summarized in Table 4.

RESULTS

Results of Formal and Informal Assessment Measures

Table 5 illustrates the results obtained from the assessment procedures. As can be seen from the table, all the subjects scored nearly perfectly on the Boehm Test of Basic Concepts, the Miller-Yoder Test and the Assessment of Children's Language Comprehension. Originally we intended to administer these tests twice to gain data which would provide pre and post measurements; however, since the lowest score obtained was 90%, we felt that no comparative data could be obtained from a second testing.

The writing samples taken from the daily tape output of the three NVPH students during the same period that the tests were administered varied in content and prose style from the test results to such a degree as to indicate that the test scores were not accurately representative of the students' linguistic abilities. The following writing examples illustrate the variance of output by the three students:

TABLE 4

Summary of Data Collection Procedures

Procedure	Application
Assessment Measures a) ACLC b) Boehm Test c) Miller Yoder Test	To obtain information on the subject's receptive language ability, level of conceptual development, and level of knowledge of syntax and grammar.
Permanent record of the subject's expressive output	1) Vocabulary usage and word frequency studies. 2) Developmental Sentence Analysis (DSA). 3) Analysis of sentence complexity other than that measured through DSA. 4) Analysis of spelling, word order, word addition and deletion errors and letter and word reversals. 5) Analysis of the subject's expressive language ability.
Daily five-minute language samples	1) Vocabulary usage and word frequency studies. 2) General analysis of linguistic structure and development. 3) Analysis of the type of communication engaged in by the child.
Teacher, questionnaires, forms and interviews	1) General informational purposes. 2) To provide, where necessary, interpretation of the subject's communication. 3) To provide specific information as to the child's educational and communication environment.

TABLE 5

Assessment Results

Name	TTR* 5/74	TTR* 9/74	Completed Sentences / Sentence Attempts in TTR 5/74	Completed Sentences / Sentence Attempts in TTR 9/74	Boehm 5/74	MY 5/74	ACLC 5/74** A	ACLC 5/74** B	ACLC 5/74** C	ACLC 5/74** D	# of Months Using A/C as of 5/74
S_{LS}	.61	.66	16/16	16/18	45 (90%)	83 (90%)	100%	100%	100%	100%	23
S_{CC}	.55	.50	7/14	5/15	50 (100%)	82 (97%)	100%	100%	100%	100%	5
S_{DC}	.61	.69	13/14	13/13	50 (100%)	84 (100%)	100%	100%	100%	100%	11

*Based on 100 word samples (Type/Token Ratio)

**With the ACLC, the child is tested on the following:

A. Vocabulary.
B. Discrimination of a sentence given two critical elements.
C. Discrimination of a sentence given three critical elements.
D. Discrimination of a sentence given four critical elements.

S_{CC}: "I saying I am girl and the 8 brat."

or

"I mov in nout hout."

S_{DC}: "We will go, but people will come there and we will go home."

or

"I think the letters will help people to talk to me now."

S_{LS}: "What book am I getting next?"

or

"I was thinking I would go up to the INC and get some records."

This discrepancy between the test results and the tape output of the NVPH students may suggest that the language tests and basic concepts tests which are available today are: 1) inadequate for assessment of linguistic competence and performance in NVPH students and/or 2) more applicable to NVPH students of ten years of age or younger.

There are very few formal assessment measures available which allow adequate appraisal of the older child's ability in these areas, especially for assessing language performance for the development of effective remedial language programs.

Since formal tests did not provide adequate appraisal of the students' language ability, informal syntactic analysis procedures were implemented.

Results of a Syntactic Analysis Measure

Procedures which involve syntactic analysis are usually implemented by collecting and studying a corpus of expressive utterances of the child. For this exploration, a corpus of utterances was collected from each child through retaining thermal print tape output of the Autocom. Developmental Sentence Scoring (DSS), a procedure developed by Lee (1974), was chosen as the measure for syntactic analysis.

DDS is "a method for making a detailed, readily quantified and scored evaluation of a child's use of standard English grammatical rules " (Lee, 1974). Constructed upon developmental stages of language acquisition, it was developed in an attempt to "adopt some of the psycholinguistic research methods and findings to a form which speech and language clinicians would find applicable and useful in working with language delayed children" (Lee, 1974).

A number of modifications were made in DSS data collection procedures for the students in this exploration. Lee (1974) based her developmental sentence analysis upon tape recorded samples of vocal children's utterances in conversation with adults. For the students in this study, language samples were obtained from the thermal print tape from the Autocom. Samples were taken from conversations resulting from the student interacting with his parents, his teacher, or his peers. The language samples were excerpted directly from the thermal tape, thus providing successive utterances of the child. (See Appendix C: Language Samples.)

Other than modifying the method of collecting language samples obtained for analysis, the DSS was conducted in the same manner as outlined by Lee (1974). All DSS scores were based upon language samples of as close to 50 sentence expressions as it was possible to obtain.

Developmental sentence scores were obtained for the students in this study during four separate periods:

1) Before the Student Used the Autocom

The language samples used for this analysis were taken from written diaries of the subject's teachers and parents.

2) Just after Receiving the Autocom

The language samples utilized for this analysis were compiled from sentences which the child expressed just after receiving the Autocom. The language samples were transcribed from a video display (TV monitor) by their parents or teachers.

3) May of 1974

These language samples were taken from the permanent thermal tape record of the child's successive utterances while he was using the portable Autocom.

4) September of 1974

These language samples were taken from the permanent thermal tape record of the child's successive utterances while he was using the portable Autocom.

The results of the NVPH students' DSS are shown in Table 6.

To summarize:

S_{LS} progressed from 5.86 to 7.43 in a time period of three years and five months;

S_{CC} regressed from 4.66 to 4.21 in a time period of five months; and

---

S_{DC} regressed from 10.94 to 8.76 in a time period of six months and then progressed from 8.76 to 10.24 in a time period of one year and five months.

Table 7 illustrates the DSS norms for the child up to 6-6, and indicates the 10th to the 90th percentile as established by Lee (1974). According to DSS procedure, a child's "language delay" is obtained by plotting his DSS at the appropriate chronological age (CA) level. A line is then drawn to the left until the same DSS score is reached on the 50th percentile. Language delay equals the child's CA at his obtained DSS minus the CA at which the normal child obtains the same DSS.

A review of individual student's progress reveals that S_{LS} progressed fairly steadily from 12-11 to 15-6. His DSS score of 5.86 at the age of 12-11 shows a language delay of approximately 108 months according to the norms established by Lee. According to these norms it also appears that during this period (from May to September 1974), S_{LS}'s language age matured nine months while his chronological age matured three years, seven months. He was receiving speech and language therapy during this time.

TABLE 6

Developmental Sentence Scoring

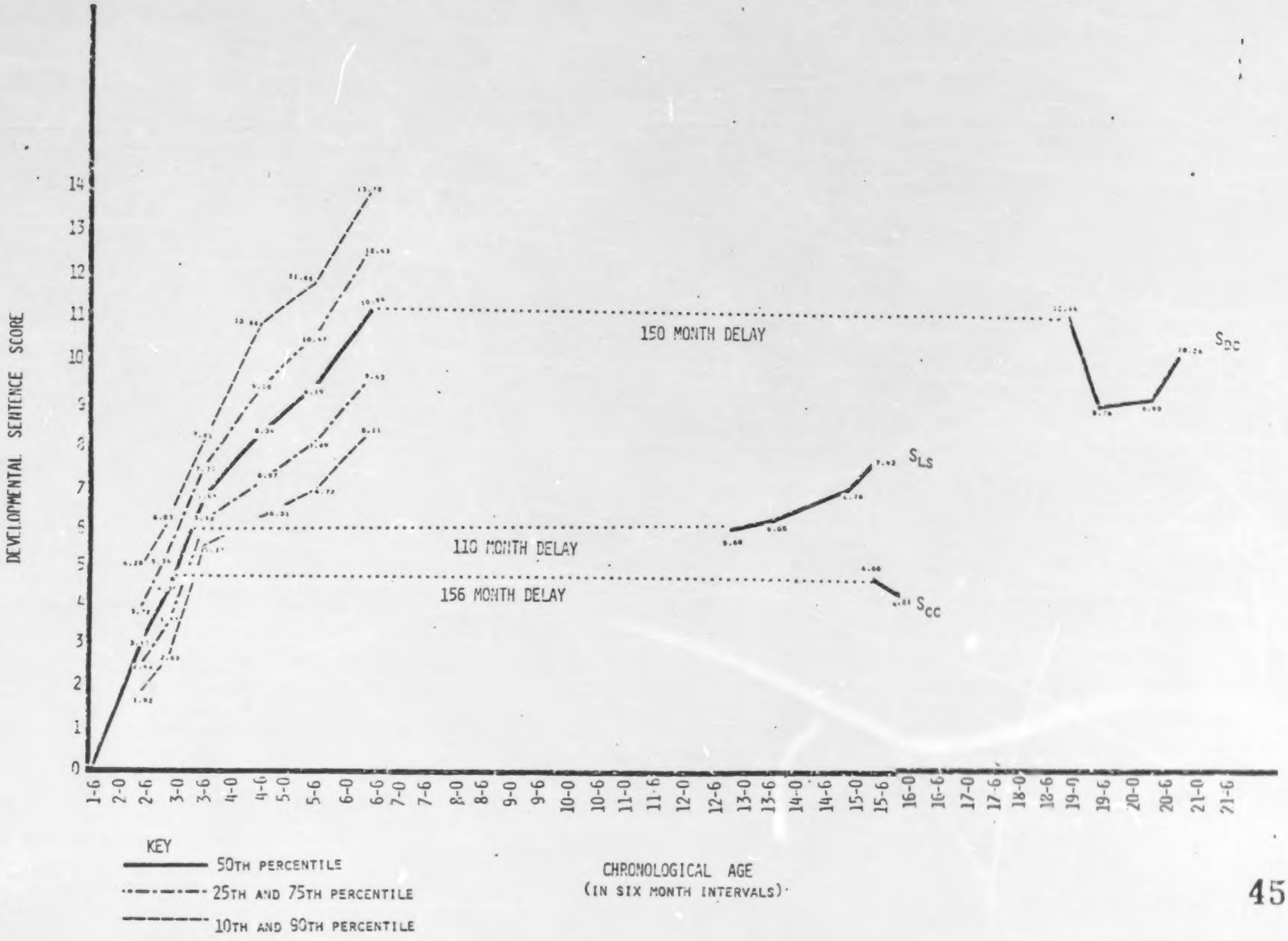
NAME	PERIOD 1			PERIOD 2			PERIOD 3			PERIOD 4		
	Pre AC			Just After Receiving AC			May 1974			Sept. 1974		
	N	DSS	Age	N	DSS	Age	N	DSS	Age	N	DSS	Age
S_{LS}	51	5.85	12-11	18	6.05	13-8	52	6.78	15-2	51	7.43	15-6
S_{CC}[1]	--	--	--	--	--	--	50	4.66	15.6	50	4.21	15-10
S_{DC}	19	10.94	19-0	50	8.76	19-6	50	8.9	20-7	53	10.24	20-11

---

[1] Data was not obtained in periods 1 or 2 for S_{CC}. S_{CC} had only yes/no communication prior to receiving the Auto-Com. During period 2, just after receiving the Auto-Com, S_{CC}'s language samples were recorded as the teacher's interpretations of S_{CC}'s sentence and not his actual output.

TABLE 7

COMPARISON OF S'S DSS TO DEVELOPMENTAL NORMS



S_{LS} CA	DSS	Language Age According to DSS Norms	Language Delay
12-11	5.86	3-3 (approx.)	8-8
13-8	6.05	3-5 "	10-3
15-2	6.78	3-11 "	12-0
15-6	7.43	3-12 "	12-5

S_{CC}'s DSS score dropped from 4.66 to 4.21 over a period of five months. This drop occurred over the summer months when he resided at home. During this time his parents reportedly did not communicate consistently with him through use of the Autocom or a letterboard and relied mostly upon interpretation of his gestures for communication. His score of 4.66 at a chronological age of 15-6 is, according to the norms, a language delay of 156 months. According to the norms (Table 7) it also appears that his language age dropped two months while his chronological age matured four months. He was not receiving language therapy during this time.

S_{LS} CA	DSS	Language Age According to DSS Norms	Language Delay
15-6	4.66	2-10	13-5
15-10	4.21	2-8	12-3

$\underline{S_{DC}}$

S_{DC}'s DSS score dropped from 10.94 to 8.76 over a six month period and then progressed from 8.76 to 10.24 over a one-year, five-month period.

According to the norms and the following table, S_{DC}'s chronological age development and language age development may be illustrated as the following:

CA	DSS	Language Age According to DSS Norms	Language Delay
19-0	10.94*	6-6	12-4
19-6	8.76	5-0	14-6
20-7	8.90	5-5	15-2
20-11	10.24	6-1	9-9

*Data from parent transcriptions prior to placement of aids

Although DSS procedures allowed a closer look at individual student's linguistic ability, the results obtained were not appropriate indicators of the students' actual competencies (Table 8). Of basic concern in the interpretation of these results was the basis upon which DSS procedures have been developed. Lee's procedure has, as a primary goal, analysis of a vocal child's spoken utterances. The language corpus used for analysis in this study consisted of written responses of non-vocal motor involved students. This latter population's language will, in nearly all cases, be delayed to some degree. Their communication depends upon the written word, and reading, writing and sequencing skills are acquired much later than vocal communication skills as evidenced in the normal child.

The utilization of syntactic analyses for studying the NVPH child's emergence of language and communication skills presented another difficulty. Research has shown that a child's first words are, for the most part, semantically determined (i.e., they are learned and used on the basis of their meaning, rather than their relationship to other words in a grammatical sentence) (Bloom, 1973). It would seem more worthwhile to investigate the NVPH student's language corpus with a semantically based analysis (such as the Berkeley Coding System (Slobin, 1975))in future explorations.

Vocabulary Probe

To compare the expressive language of the NVSPH children using communication aids to normal vocal individuals, spoken word counts were compiled on the 3 students using the portable aids. The word counts for the NVSPH list were taken from the continuous daily expressive output of the 3 students in the study (ages 14, 19, 19). The "normal adult" wordlist came from a study by L. Jones and J. Wepman (1966). These words were tabulated from "predominantly older" adults who were discussing pictures from the Thematic Apperception Test.

Table 8

Comparison of DSS Scores and Language Samples

Student	DSS	DSS Language Age	Language Sample
S_{CC}	4.6-4.2	2,10-2,8	I caom home ane I aet pig (pork). T: I came home and I ate pork. I com from school and I aet stad. T: I come from school and I eat steak. Go and whos the jrims and whos plick pot in jrim. T: Go and wash the jars and wash the pickles. Put (the pickles) in jar.
S_{LS}	5.8-7.4	3,3-3,12	I want you to come down this summer on a sunday like you did last year. You blap (blab) it around aniaway (anyway). What are thouse (those) for? I was thinking I would go up to the ING and get some records.
S_{DC}	8.7-10.9	5,0-6,1	I think that this is much better to talk with people. Oh! I want to go to Kmart with you. We want to talk to you please. I looking for house for handicapped persons.

Results of the word counts for the NVSPH individuals are presented in Tables 9 (Frequency) and 10 (Alphabetical). Since some of the words appeared on the surface of the aids as words where others needed to be spelled out, the preprinted (wordmaster) words are marked on the lists. Because of the limited size of the sample due to hand transcription, many of the words in the NVSPH list are idiosyncratic. The results of the rankings, however, are quite similar to spoken word counts. Approximately 42% of the first 50 words in both counts were common. Somewhat surprisingly, this same figure held for the first 100 and 200 words. It was expected that the lists would diverge as they became larger due to the different subject matter and contexts of the "speakers" in the two groups. To further check overlap of the lists comparisons of the first 50 NVSPH wordlist items were made to larger portions of the "normal adult" word counts. The results showed that approximately half of the 50 most frequently used NVSPH words which weren't in the top 50 "nonoral adult" words were found in the next 50. The results can be summarized:

TABLE 11: Summary of Comparison of First 50 NVSPH Word List to Larger Portions of "Normal Adult" Word List

COMMON	%
21	42% of top 50 words of both lists were common
47	47% of top 100 words of both lists were common
84	42% of top 200 words of both lists were common
36	72% of top 50 NVSPH words in top 100 nonoral
70	70% of top 100 NVSPH words in top 200 nonoral
41	82% of top 50 NVSPH words in top 200 nonoral

The word counts were further broken down by general grammatical class. Profiles within each wordlist were made as well as profiles of the words common to the two lists (Table 12). The results showed that there were more verbs among the common words (line 1) than would have been predicted from the breakdown of the individual lists (lines 2 and 3). Also predictably the comparison of the common words (line 6) showed that a smaller portion of the nouns and modifers of the two lists were common than the verbs or other words.

Although the results are an interesting first look, more information is needed in order to do more direct comparison. Whereas the comparisons of "conjunction" and "other" words may be appropriate, there is some question as to the comparison of content words such as the nouns, verbs, and modifiers, given the great difference in the content and function of the two groups' communications. The age difference and communication experience difference of the speakers also must be taken into account, as must the speed at which the individuals must communicate (slower speed may yield simpler sentences) and the fact that their communication is conversational-written communication. It is these last two factors that are of most importance to researchers at the present time as they try to develop wordsets and vocabularies which can allow the NVSPH individual to communicate more easily and rapidly.

Table 9

WORD FREQUENCY LIST[1]

BY FREQUENCY

WORDLIST II MARKED

Words which appeared more than once in the total sample of 3892 words are listed in the order of frequency with which they occurred.

		Rank			Rank			Rank
I	248	2	#come	19	35	day	10	70
#is	248	2	##hurt	19	35	Friday	10	70
#to	103	3	Mr. Caswell	18	36	they	10	70
#and	97	4	##know	17	39	##tomorrow	10	70
#the	83	5	#think	17	39	don't	9	72
#it	82	6	#want	17	39	Madison	9	72
#you	57	7	## love	16	43	portable	8	80
a	52	8	this	16	43	red	8	80
#I'm	49	9	#will	16	43	talk	8	80
#me	40	16	##would	16	43	##thanks	8	80
#my	40	19	#give	15	47	##today	8	80
#in	38	12	going	15	47	##when	8	80
#have	37	13	mom	15	47	##where	8	80
#go	35	15	we	15	47	your	8	80
##good	35	15	of	13	48	##feel	7	93
#are	31	16	at	12	53	Gregg	7	93
#see	30	17	Dad	12	53	had	7	93
#like	29	18	##eat	12	53	he	7	93
#for	28	20	##get	12	53	home	7	93
#on	28	20	got	12	53	hot	7	93
#not	26	21	Autocom	11	54	Jill	7	93
am	25	24	##bathroom	11	54	##make	7	93
#now	25	24	be	11	54	man	7	93
#that	25	24	camp	11	54	movie	7	93
#do	24	25	dear	11	54	ok	7	93
##because	23	26	##friend	11	54	people	7	93
#can	22	30	Jack	11	54	school	7	93
#how	22	30	##play	11	54	all	6	114
##what	22	30	## some	11	54	back	6	114
#with	22	30	##take	11	54	board	6	114
hi	21	32	went 2213	11	54	bring	6	114
##please	21	32	##about 54%	10	70	children	6	114
##look 1668	20	33	CPCG	10	70	daughter	6	114
43%								

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

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[1] It should be noted that words which were misspelled were included in the word frequency count, if it could be determined that the child understood correct use of the word by looking at the context in which he used the word.

		Rank			Rank			Rank
Debbi	6	114	mean	4	160	outside	3	209
fun	6	114	miss	4	160	remember	3	209
girl	6	114	##more	4	160	rest	3	209
happy		114	out	4	160	sew	3	209
birthday	6	114	saw	4	160	show	3	209
having	6	114	Sunday	4	160	sick	3	209
hope	6	114	Wendt	4	160	something	3	209
independent	6	114	wheelchair	4	160	try	3	209
life	6	114	##why	4	160	until	3	209
our	6	114	wish	4	160	used	3	209
parents	6	114	Wordmaster	4	160	well	3	209
picture	6	114	writing	4	160	alot	2	273
she	6	114	act	3	209	ask	2	273
TV	6	114	algebra	3	209	child	2	273
watched	6	114	aware	3	209	Creer	2	273
year	6	114	cabin	3	209	CP	2	273
around	5	133	classes	3	209	dumb	2	273
ate	5	133	close	3	209	end	2	273
bar	5	133	could	3	209	expect	2	273
beautiful	5	133	Daddy	3	209	fair	2	273
communicate	5	133	different	3	209	fast	2	273
counselor	5	133	director	3	209	father	2	273
dorm	5	133	doctor	3	209	film	2	273
from	5	133	dog	3	209	find	2	273
handicapped	5	133	doing	3	209	first	2	273
Harold	5	133	exam	3	209	fish	2	273
Lydell	5	133	everyone	3	209	free	2	273
move	5	133	everywhere	3	209	graduate	2	273
nut	5	133	getting	3	209	happen	2	273
##repeat	5	133	glad	3	209	hard	2	273
sometimes	5	133	good	3	209	higher	2	273
##sorry	5	133	group	3	209	home ec	2	273
##stop	5	133	heel	3	209	ice	2	273
tape	5	133	here	3	209	it's	2	273
very	5	133	house	3	209	last	2	273
before	4	160	lake	3	209	little	2	273
building	4	160	legs	3	209	listened	2	273
bingo	4	160	letter	3	209	lunches	2	273
boy	4	160	mad	3	209	midnight	2	273
but	4	160	mail	3	209	morning	2	273
by	4	160	many	3	209	mostly	2	273
Craig	4	160	mark	3	209	mother	2	273
can't	4	160	marry	3	209	newspaper	2	273
did	4	160	may	3	209	next	2	273
##every	4	160	maybe	3	209	night	2	273
Gompers	4	160	much	3	209	note	2	273
guess	4	160	name	3	209	one	2	273
hate	4	160	need	3	209	pat	2	273
him	4	160	no	3	209	pig	2	273
if	4	160	old	3	209	place	2	273

#Level 1 Wordmaster words - Wordlist II
##Level 2 Wordmaster words - Wordlist II

		Rank
pop	2	273
pot	2	273
put	2	273
radio	2	273
received	2	273
respond	2	273
sack	2	273
said	2	273
sing	2	273
so	2	273
soft	2	273
speech	2	273
steak	2	273
store	2	273
sun	2	273
swimming	2	273
table	2	273
tell	2	273
there	2	273
together	2	273
too	2	273
ugly	2	273
use	2	273
while	2	273
without	2	273

TABLE 10

WORD FREQUENCY LIST

ALPHABETICAL

WORDSET I WORDS MARKED

Words which appeared more than once in the total sample of 3892 words are listed in alphabetical order along with their frequency of occurrence.

WORD	FREQ	NVSPH RANK	VOCAL ADULT RANK
a	52	8	4
about	10	70	45
act	3	209	360
Algebra	3	209	--
all	6	114	865
alot	2	257	--
am	25	24	100
and	97	4	3
are	31	16	38
around	5	133	155
ask	2	257	--
at	12	53	56
ate	5	33	--
Autocom	11	64	--
aware	3	209	--
back	6	114	124
bar	5	133	--
bathroom	11	64	--
be	11	64	13
beautiful	5	133	--
because	23	26	96
before	4	160	--
Bingo	4	160	--
board	6	114	--
boy	4	160	110
bring	6	114	366
building	4	160	330
but	4	160	30
by	15	41	87
cabin	3	209	--
camp	11	64	1000
can	22	30	48
can't	4	160	--
Mr. Caswell	18	36	--
child	2	257	229
children	6	114	353
classes	3	209	--
close	3	209	315
come	19	35	73
communicate	5	133	--
could	3	209	55
counselor	5	133	--
CP	2	257	--
CPCG	10	70	--
Craig	4	160	--
Creer	2	257	--
Dad	12	53	--
Daddy	3	209	---
daughter	6	114	147
day	10	70	154
dear	11	64	441
Debbi	6	114	--
did	4	160	151
different	3	209	311
director	3	209	--
do	24	25	19
doctor	3	209	341
dog	3	209	--
doing	3	209	--
don't	9	72	--
dorm	5	133	--
dumb	2	257	--
eat	12	53	864
end	2	257	215
every	4	160	408
everyone	3	209	--
everywhere	3	209	--
exam	3	209	--

It should be noted that words which were misspelled were included in the word frequency count, if it could be determined that the child understood correct use of the word by looking at the context in which he used the word.

expect	2	257	358
fair	2	257	--
fast	2	257	--
father	2	257	164
feel	7	93	187
film	2	257	--
find	2	257	197
first	2	257	291
fish	8	80	--
for	28	20	49
free	2	257	--
Friday	10	70	--
friend	11	64	337
from	5	133	60
fun	6	114	--
get	12	53	65
getting	3	209	--
girl	6	114	94
give	15	47	146
glad	3	209	583
go	35	15	35
going	15	47	--
Gompers	8	80	--
good	35	15	114
got	12	53	92
graduate	2	257	--
Gregg	7	93	--
group	3	209	448
guess	4	160	152
had	7	93	40
handicapped	5	133	--
happen	2	257	135
Happy Birthday	6	114	--
hard	2	257	144
Harold	5	133	--
hate	4	160	--
have	37	130	31
having	6	114	--
he	7	93	9
heel	3	209	--
here	3	209	54
hi	21	32	--
higher	2	257	--
him	4	160	40
home	7	93	118
home ec	2	257	--
hope	6	114	223
hot	7	93	--
house	3	209	173
how	22	30	128
hurt	19	35	434
I	248	2	6
ice	2	257	575
if	4	160	62
I'm	49	9	--
in	38	12	14
independent	6	114	--
is	248	2	1
it	82	6	8
it's	2	257	--
Jack	11	64	--
Jill	7	93	--
know	17	39	29
lake	3	209	--
last	2	257	313
legs	3	209	--
letter	3	209	--
life	6	114	130
like	29	18	18
listened	2	257	--
little	2	257	77
look	20	33	15
love	16	43	264
lunches	2	257	--
Lydell	5	133	--
mad	3	209	--
Madison	9	72	--
mail	3	209	--
make	7	93	84
man	7	93	46
many	3	209	230
mark	3	209	--
marry	3	209	--
may	3	209	117
maybe	10	70	74
me	40	16	63
mean	4	160	148
midnight	2	257	--
miss	4	160	--
mom	15	47	--
more	4	160	113
morning	2	257	--
mostly	2	257	--
mother	2	257	76
move	5	133	--
movie	7	93	--
much	3	209	82
my	40	19	129
name	3	209	--
need	3	209	--
newspaper	2	257	--
next	2	257	328
night	2	257	225

no	3	209	87
not	26	21	12
note	2	257	--
now	25	24	86
nut	5	133	--
of	13	48	10
ok	2	257	--
old	3	209	108
on	28	20	23
one	2	257	48
our	6	114	--
out	7	133	43
outside	3	209	--
parents	6	114	--
pat	2	257	--
people	7	93	122
picture	6	114	53
pig	2	257	--
place	2	257	206
play	11	64	208
please	21	32	--
pop	2	257	--
portable	8	80	--
pot	2	257	--
put	12	53	--
radio	2	257	--
received	2	257	--
red	8	80	--
remember	3	209	--
repeat	5	133	--
respond	2	257	--
rest	3	209	352
sack	2	257	--
said	2	257	--
saw	4	160	--
school	7	93	177
see	30	17	47
sew	3	209	--
she	6	114	11
show	3	209	204
sick	3	209	258
sing	2	257	--
so	2	257	58
soft	2	257	--
some	11	64	51
something	3	209	39
sometimes	15	47	--
sorry	5	133	383
speech	2	257	--
steak	2	257	--
stop	5	133	--
store	2	257	--
sun	2	257	379
Sunday	4	160	--
swimming	2	257	--
table	2	257	247
take	11	64	109
talk	8	80	212
tape	5	133	--
tell	2	257	81
thanks	8	80	--
that	25	24	7
the	85	5	2
there	2	257	21
they	10	70	27
think	17	39	28
this	16	43	16
to	103	3	5
today	8	80	--
together	2	257	288
tomorrow	10	70	--
too	2	257	100
try	3	209	67
TV	6	114	--
ugly	2	257	--
until	3	209	--
use	2	257	246
used	3	209	--
very	5	133	33
want	17	39	88
watched	6	114	305
we	15	47	101
well	3	209	24
Wendt	4	160	--
went	11	64	277
what	22	30	22
wheelchair	4	160	--
when	8	80	138
where	8	80	123
while	2	257	--
why	4	160	214
will	16	43	38
with	22	30	44
without	2	257	--
wish	4	160	--
Wordmaster	4	160	--
would	16	43	34
writing	4	160	--
year	6	114	--
you	57	7	37
your	8	80	--

TABLE 12
'MOST FREQUENT WORDS' COMPARISON
ADULT NORMAL INDIV. (JONES-WEPMAN)
VS.
NVSPH ADOLESCENT INDIV. (HARRIS-VANDERHEIDEN)

	MOST FREQUENT WORDS COMP.	Nouns	Verbs	Modifiers	Conj.	Other	Total
1.	words common to top 100 words of both	11	21	1	2	12	47
	% of 47 common words in each category	23%	45%	2%	4%	26%	100%

	BREAKDOWN OF JW NORMAL ADULT WORDS	Nouns	Verbs	Modifiers	Conj.	Other	Total
2.	# of top 100 in each category	26	31	14	8	21	100
	% of top 100 in each category	26%	31%	14%	8%	21%	100%

	BREAKDOWN OF NVSPH WORDS	Nouns	Verbs	Modifiers	Conj.	Other	Total
3.	# of top 100 in each category	36	35	10	2	17	100
	% of top 100 in each category	36%	35%	10%	2%	17%	100%
4.	% of JW Normal Adult words in each category that was common $(\% = \frac{\text{common}}{\text{JW category total}})$	$\frac{11}{26}$=42%	$\frac{21}{31}$=67%	$\frac{1}{14}$=7%	$\frac{2}{8}$=25%	$\frac{12}{21}$=57%	$\frac{47}{100}$=47%
5.	% of NVSPH words in each category which were common $(\% = \frac{\text{common}}{\text{NSVSPH total}})$	$\frac{11}{36}$=30%	$\frac{21}{35}$=60%	$\frac{1}{10}$=10%	$\frac{2}{2}$=100%	$\frac{12}{17}$=70%	$\frac{47}{100}$=47%
6.	Mean % of words in each category which were common $(\frac{\text{common words}}{1/2\ (\text{JW wds} + \text{NVSPH wds})})$	35%	64%	8%	40%	63%	47%

1. Jones-Wepman (1966)
2. Harris-Vanderheiden

Discussion of Preliminary Exploration Results

This preliminary evaluation revealed several problems and critical concerns which need to be alleviated before thorough investigation of language development in the NVPH child can be initiated. As mentioned previously, methods for assessing linguistic competence should be made more appropriate to the NVPH child. Formal assessments have been developed for and normed on normal, manipulative, ambulatory vocal children and may, therefore, require extensive modification to be appropriate for the NVPH child. Rather than develop new tests, or go through extensive test modification, appropriate appraisal of linguistic ability may be assessed through informal analysis techniques. Most informal techniques (such as DSS) are syntactically based, however, and semantically based analyses appear to be more appropriate to the type of investigation under discussion. An extensive review of linguistic assessment techniques utilizing corpuses of children's expressive output is warranted prior to further investigation into language development processes in this population.

A second concern involves data collection procedures. Thermal print tape was collected and analyzed in the preliminary exploration, but a number of problems ensued. First, the tapes had to be manually collected and saved by the student's teacher or parent throughout the day. The size and strength of the tape necessitated careful handling. Since the tape was easily ripped, researchers could not rely upon obtaining truly sequential utterances. Mailing tape back to the research group was bulky, and, for the researchers, coiled, torn tape was difficult to transcribe. In addition, timed samples were difficult to record.

Although the tape samples allowed reasonable initial investigation of expressive output, a more efficient, reliable and systematic method of data collection is necessary for more rigorous investigations.

In an effort to develop a highly reliable, systematized and automatic method of collecting a language corpus from NVPH children, the Trace Center has developed a sub-miniature data-recording unit which can be placed inside electronic communication aids. The entire unit is approximately the size of a normal cassette tape cartridge and can be placed directly into the communication aid. The miniature tape cartridge of the data-recorder is able to store 400,000 bits of information or 50,000 letters without having to be replaced.

Through use of the data-recorder, researchers will be able to obtain timed samples of the child's expressive output, as the data-recorder automatically "marks" the tape once every minute. In addition, the data-recorder information is computer analyzable and, through use of a computer with a video display, researchers will be able to review the child's expressive communication from any designated point in time (except where information has been coded confidential). Through this method the child's expressive communication can be completely reconstructed and researchers will be able to determine the length of time needed to construct the utterance, the mistakes made by the child in constructing his response along with the corrections performed, and the final expressive output.

A typical analysis of the child's expressive communication through computer analysis of data-recorder information would yield information such as the following:

1) Words most frequently used by the child and type-token ratios.

2) Sentences within which those words most frequently appear.

3) Amount and ratio of the child's expressive communication as measured over time.

4) Average length of words used by the child, as measured over time.

5) Average length of the child's phrases and/or sentences as measured over time.

6) Grammatical and syntactical structure of sentences expressed by the child.

7) Complete transcription of the child's expressive communication, and ability to reconstruct, at any time, the child's total expressive communication (exclusive of censored communication).

8) Timed samples of the child's communication which will be correlated with information from video and audio recordings pertaining to the concurrent linguistic environment and communicative interaction.

With computer analysis of the data-recorder information researchers will be able to re-construct the child's utterance, study the corrections the child made in his utterances in order to come to final output, and determine the total amount of time needed to write the thought or idea. This information could then be cross-correlated with timed information from audio and visual recordings so that an entire linguistic environment (to a certain extent) could be reconstructed at selected times during the study.

Besides affording researchers these options, computer analysis will save valuable transcription time. Brown (1973) estimated that it took researchers approximately four hours to transcribe one hour of recorded tape of the vocal child. Although the computer itself cannot analyze data, it will save valuable time for the researchers.

This data-recording aid will allow accurate, automatic analysis of syntactic aspects of NVPH children's expressive output. Since it could be placed in a variety of different types of aids, it will allow researchers to study the expressive output of a number of children with differing motor handicaps who are utilizing different modes of communication. Thus, a comparative analysis of the effect of the type of communication aid used upon a child's production skills could be implemented.

Observations

Although methodological problems were revealed in our preliminary exploration, some interesting observations were noted as well. Of primary interest was the observation that students who had been non-verbal, or who had had limited communication skills, rapidly acquired language and communication skills once provided with an effective mode of responding and communicating. The student in this study who had only yes/no communication prior to the Autocom began to produce phrases and sentences when he acquired a production syntax. He did not go through a "one word" phase. This observation needs further research and may have implications for the processes and progress involved in the development of comprehension and production skills in NVPH children.

Further explorations in this area are needed, and a large corpus of expressive output needs to be collected before researchers can probe specific questions.

FUTURE RESEARCH

Based upon observation during pilot explorations, it appears that NVPH children acquire linguistic competence through a comprehension mode and, when given an effective means of communication, are able to "transfer" this knowledge to a production mode and rapidly acquire English syntax. Some evidence toward this hypothesis was found in the pilot study where non-vocal children rapidly developed rule-governed production syntax shortly after being provided with an effective communication aid, when they previously had had very limited expression.

Research into this hypothesis should be implemented through assessment of the children's comprehension skills both prior to utilizing an effective production means and after they are provided with communication aids which will give them effective production means. Additional analysis should be made of the children's production syntax as they develop communication skills using the communication aid. Concurrent exploration should be made into: 1)the grammar evidenced in the children's production syntax; 2) the content of their production (and underlying semantic notions); and 3) the syntax and semantics of their communicative interaction with the other persons in their environment.

Specific Aims and Objectives of Continued Exploration

Continued exploration in this area should include the following types of goals and objectives:

1) exploration of production syntax and the semantic features of language development in NVPH children.

2) development of specific experimental probes into NVPH children's comprehension and production knowledge based upon

analysis of the data obtained in the first step.

3) systematic recording and storing of the language corpus obtained during initial investigations so that they can be used in and for further experimental probes.

A summary of major project objectives along with proper data collection and analysis methodologies which could be implemented in order to achieve these objectives is presented in Table 13. In addition to these methods, information pertaining to the child's use of a communication aid in various environments; to the individuals to whom the child addresses his communication; and to the changes in his use of a communication aid over a period of time is presented.

SUMMARY: SIGNIFICANCE OF PROPOSED RESEARCH

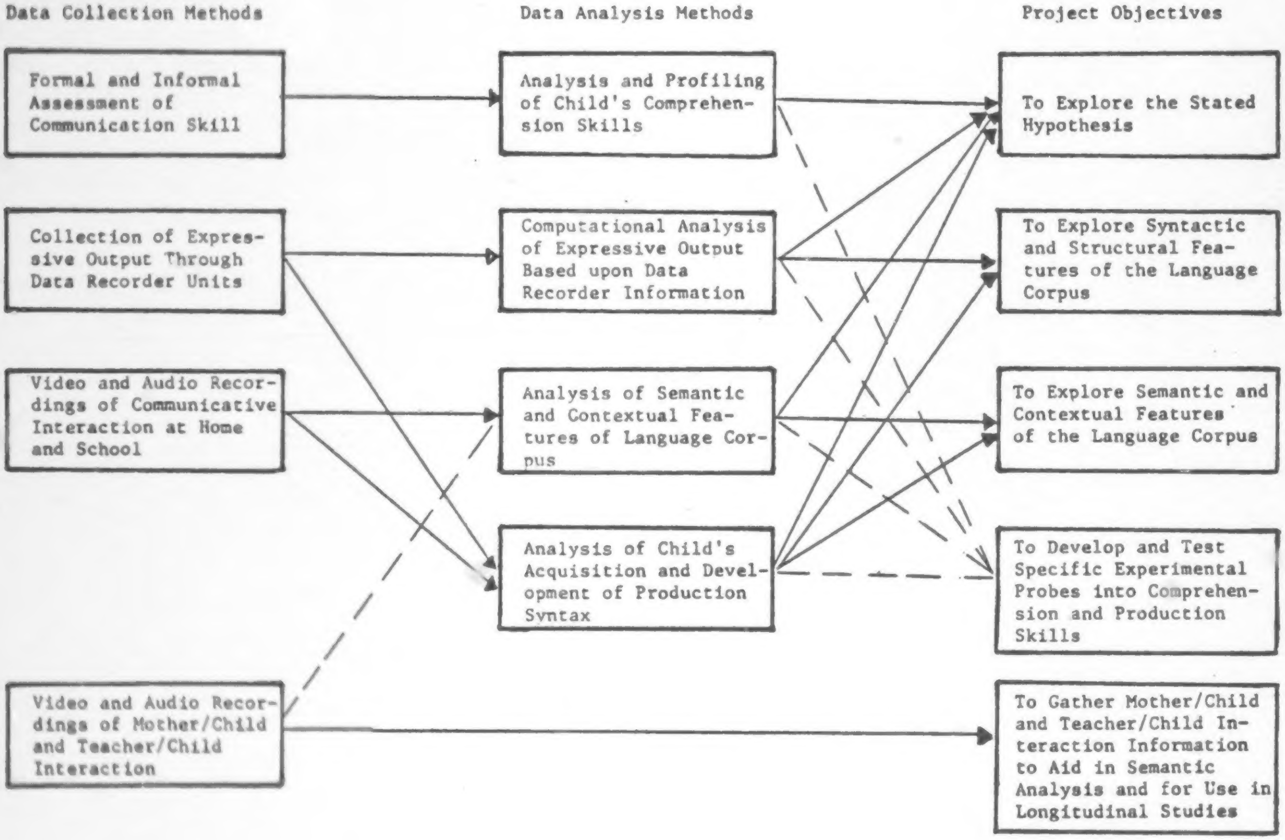
The data which can be obtained from exploratory research such as this is currently unavailable, yet of critical importance if developmental language processes of non-vocal severely handicapped children are to be systematically explored and studied. With the communication data and information generated by such studies, researchers will, for the first time, have possession of substantial data with which to begin systematic exploration of developmental language processes of this population.

The results of this research will affect many areas of communication and language development of non-vocal severely handicapped individuals. Of primary importance is the effect that these research results will have on current attempts to develop communication and language assessment methods and procedures for these children. NVPH children's linguistic ability is, at present, assessed through modification of tests specifically designed to assess the oral language development of the vocal child. Results of these tests may not always be indicative of the non-vocal handicapped child's linguistic capability. Through research such as that outlined, more will become known about the linguistic capabilites and development of these children, and consequently, more appropriate assessment and intervention procedures can be developed.

Another important aspect of providing a communication system for the non-vocal motorically impaired child (who may have varying degrees of cognitive ability) is the selection of vocabulary content for use with communication aids. The selection of vocabulary may have an important effect upon both the quantity and the quality of the child's expressive communication. Words and symbols chosen for vocabulary systems should be those which will be most functional for the child. Through studying the NVPH child's expressive output, researchers, teachers and clinicians will be able to determine those words and phrases which are most frequently used and most functional for the NVPH child, and this knowledge will be useful when planning content for communication and language programs.

Finally, this research will provide valuable input toward the develop-

Table 13. Summary of Major Project Objectives and Methods


Data Collection Methods
Data Analysis Methods
Project Objectives
Formal and Informal Assessment of Communication Skill
Collection of Expressive Output Through Data Recorder Units
Video and Audio Recordings of Communicative Interaction at Home and School
Video and Audio Recordings of Mother/Child and Teacher/Child Interaction
Analysis and Profiling of Child's Comprehension Skills
Computational Analysis of Expressive Output Based upon Data Recorder Information
Analysis of Semantic and Contextual Features of Language Corpus
Analysis of Child's Acquisition and Development of Production Syntax
To Explore the Stated Hypothesis
To Explore Syntactic and Structural Features of the Language Corpus
To Explore Semantic and Contextual Features of the Language Corpus
To Develop and Test Specific Experimental Probes into Comprehension and Production Skills
To Gather Mother/Child and Teacher/Child Interaction Information to Aid in Semantic Analysis and for Use in Longitudinal Studies

ment and verification of language development theory, both in providing contributing data for current theories of oral language development, and in providing initial data on non-vocal language development in handicapped populations.

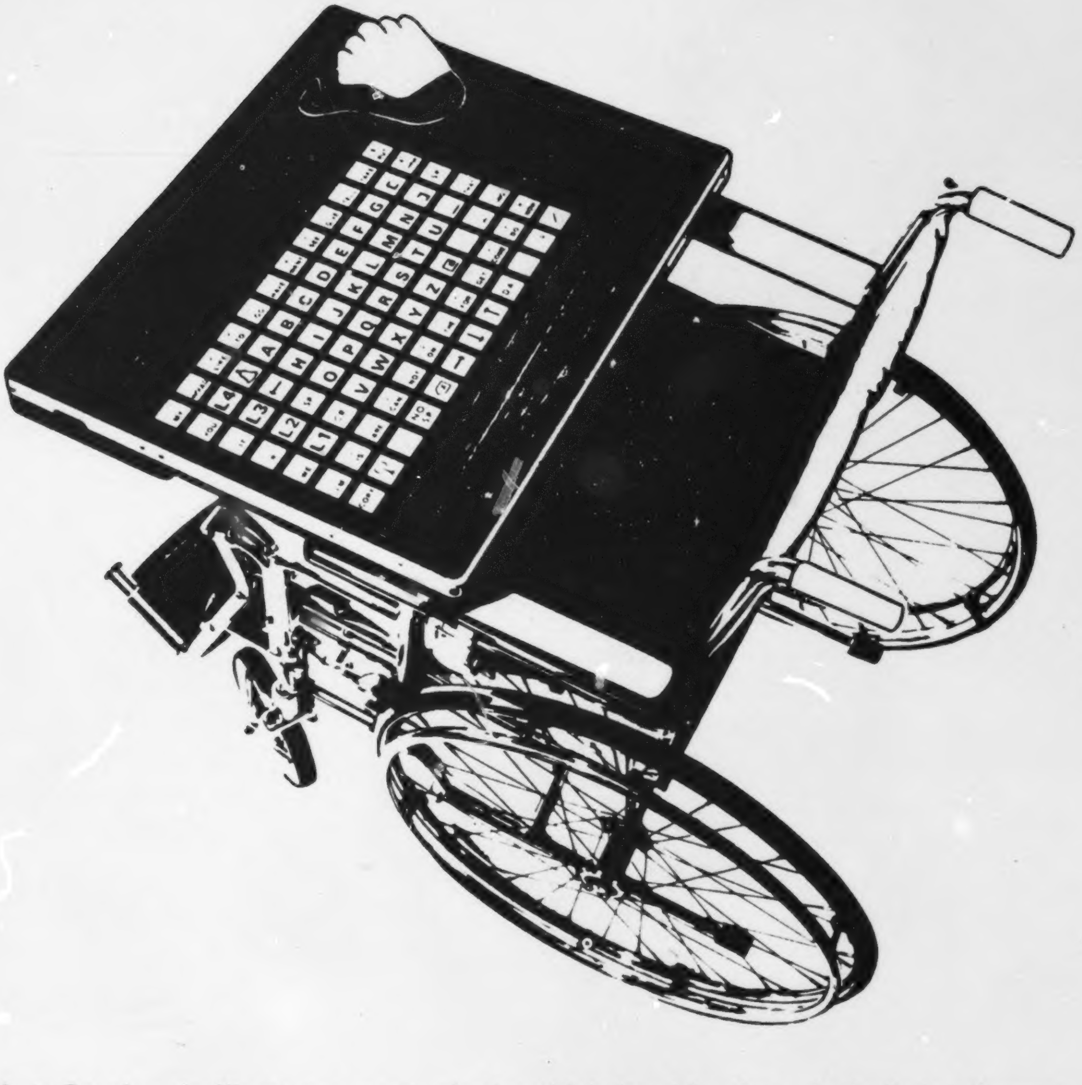
APPENDICES

APPENDIX A

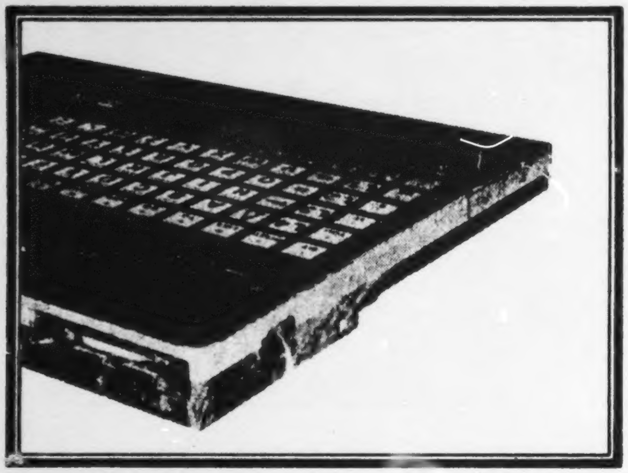
FURTHER INFORMATION ON THE AUTOCOM

The AUTO-COM™

An Auto-Monitoring Communication Board

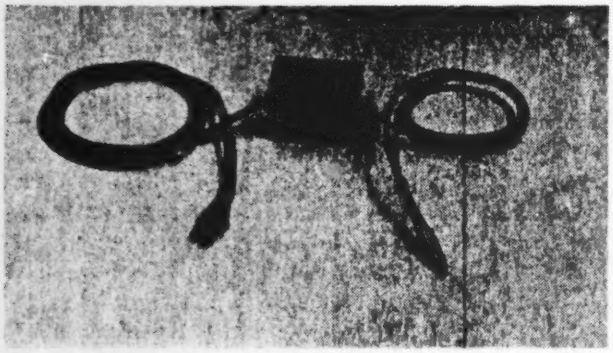


The Auto-Com is a significant new communication aid designed for those physically handicapped persons who have had to rely on manual communication boards as their primary expressive mode of communication. Designed especially for use by cerebral palsied children, the Auto-Com requires only minimal pointing skills to operate. These pointing skills can be with the hand, head, wrist, foot or any other part of the body with which the child can point. Initial results of an evaluation program indicate that any person who is capable of using a communication board should be able to achieve independent communication through use of the Auto-Com. The Auto-Com is also suitable for use by other types of physically handicapped persons who possess rough pointing skills but lack fine motor control.

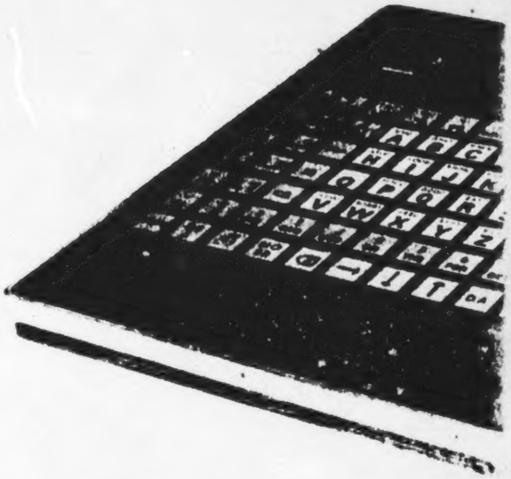


Completely portable operation is possible because of the Auto-Com's internal rechargeable battery pack and sub-miniature strip printer.

An overnight charge from the battery charger will last through the heaviest days use.



For education, recreation, and employment the Autc
can be connected directly to a television display or C
This provides the user with excellent visual feedback
100% correctability.

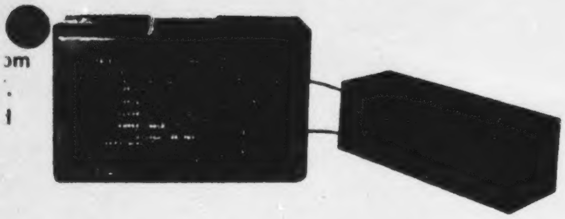


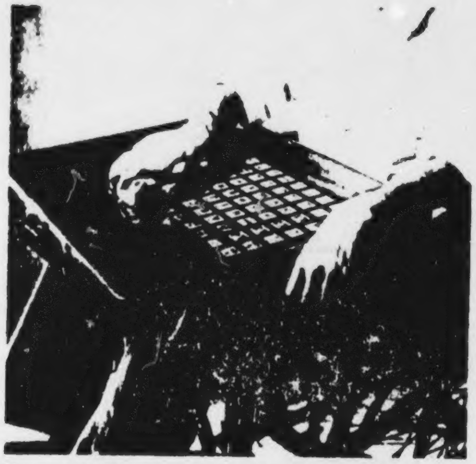
The AU

Operation

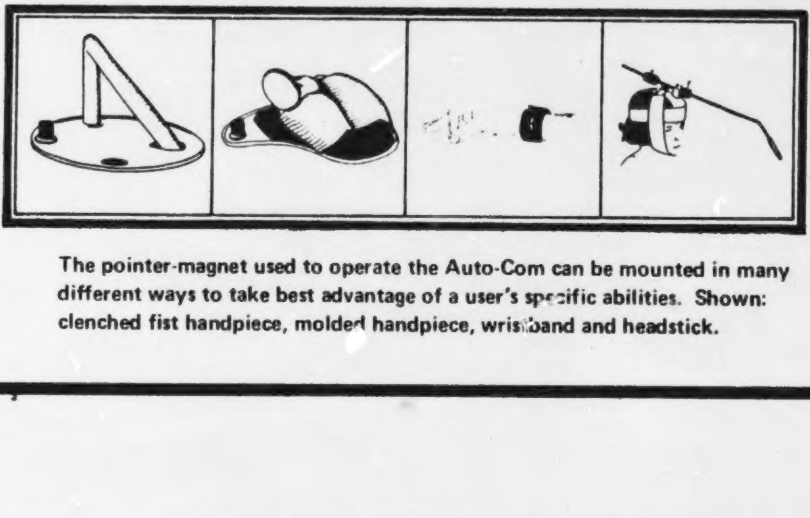
The Auto-Monitoring Communication Board (Auto-Com) is a completely independent communication aid built into a special wheelchair laptray. It has a smooth, flat Formica-like surface on which letters, numbers and commonly used words have been printed. This Auto-Monitoring Communication Board (Auto-Com) is operated in the same manner as a traditional communication board except that a magnet is used in pointing to the various letters instead of a finger, knuckle, headstick, etc. A special magnetic sensing system inside the lapboard tracks the position and movement of the pointer-magnet and prints out the letters or words as the user points to them. This system has been designed to handle a wide range of pointing abilities, including the erratic pointing motions of cerebral palsied children.

The heart of the Auto-Com is the Auto-Monitoring technique. This technique combines a matrix of wide angle magnetic proximity switches with a delay activation mechanism to produce a sensing system which is sensitive to reduction of movement rather than to discreet movements as in traditional switching arrangements. This insensitivity to erratic movements causes the Auto-Com to ignore small tremors as well as momentary loss of control due to spasms or over-excitement. The delay activation mechanism also allows the user to slide his hand around over the surface of the board when moving between selected letters. Momentarily pointing to letters as he moves over them will not cause them to print out. The user is therefore able to use the smooth surface of the Auto-Com to increase his hand control or to support the weight of his hand if he is weak.





Mounted directly on the wheelchair, the Auto-Com can be used as a worktray when not being used to communicate. In this manner it is always in front of the user but never in the way.



The pointer-magnet used to operate the Auto-Com can be mounted in many different ways to take best advantage of a user's specific abilities. Shown: clenched fist handpiece, molded handpiece, wristband and headstick.

TO-COM

Features

The Auto-Com is completely contained within a 18" x 24" x 1½" lapboard. It is wheelchair mountable, using standard Everest & Jennings wheelchair brackets. An internal, rechargeable battery pack and built-in miniature strip printer make the unit completely self-contained and fully portable. The Auto-Com, which weighs only 13 lbs., also has a handle for ease in transportation.

The Auto-Com's hard, smooth surface allows it to be also used as an ordinary laptray. Thus, the board can be used for eating, playing or work, when not being used for communication, and is therefore always available in front of the child.

In addition to printing the letters of the alphabet, numbers, mathematical symbols and punctuation, the Auto-Com also has the ability to print out entire words, phrases and sentences with single pointing motions. The Auto-Com's memories may contain up to 192 eight-letter words, 128 of which may be selected by the user. The "Wordmaster" option not only increases the speed of communication for Auto-Com users, but also allows children who are not yet able to spell to communicate using the Auto-Com.

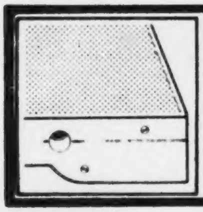
The Advantage of Auto-Monitoring ™

The Auto-Com is very similar, both in appearance and operation, to the ordinary communication board or language board. In both cases the child communicates by pointing to letters or words which are printed or painted on the hard, smooth surface, to indicate the message. With a traditional board, however, a second person is needed to monitor the child's erratic pointing,to memorize or record which letters or words he is trying to indicate,and to determine his message. This is time-consuming and demands the total attention of the second person.

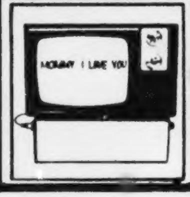
The Auto-Com, however, monitors and determines the correct letter automatically, printing it out for the child. In this manner the child is able to communicate completely independently. The person he is talking to need only take a short time to read the message to find out what the child has said. This is of particular value in the classroom where the teacher has limited time to spend with each student. With an Auto-Com, the child is able to compose his message on his own, requiring no more time of the teacher than a normal question or comment. This allows the child to participate much more fully in class activities including lectures, discussions, and question and answer periods. In addition, the child has a means of doing independent work, homework and exams.

ALTERNATE OUTPUT FORMS

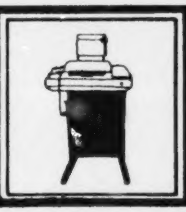
In addition to the subminiature strip printer, the Auto-Com™ can directly control a large variety of other output devices.



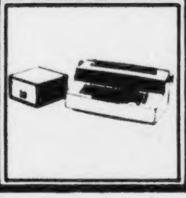
Standard output Form (ASCII) allows auto-com to directly control computers etc.



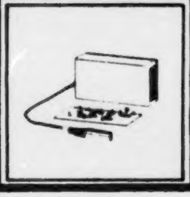
Television or CRT Display for LARGE clear versatile and correctable display



Teletypwriter low cost form printed output non-correctable



Correctable IBM selectric-modified a highly versatile form of printed output



Transmitter link allows Auto-Com to control any output device by radio control

VOICE
(under development)

Vocal interface to facilitate conversational or group communication

---

The Cerebral Palsy Communication Group, an interdisciplinary student team at the University of Wisconsin, is working on the communication problems faced by non-vocal severely handicapped children. The group initially concentrated on the communication problems of the cerebral palsied, but has now expanded the scope of its efforts to cover all forms of handicapping conditions which leave an individual unable to communicate through speech or writing.

CPCG
Cerebral Palsy Communication Group
University of Wisconsin-Madison

922 ERB, 1500 Johnson Drive, Madison, Wisconsin 53706, 608 262 6966

This work is supported by Grant EC-40316 of the National Science Foundation and Grant OEG-0-74-7461 of The Bureau for the Education of the Handicapped, Office of Education (HEW).

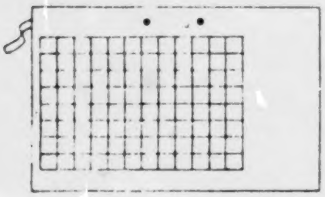
UPDATE: NEW FEATURES OF THE AUTO-COM

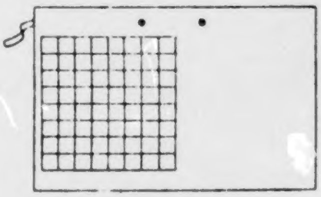
Built-In 30 Character Display

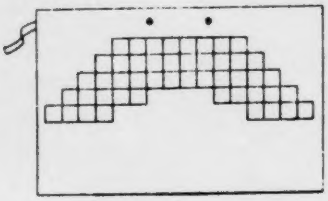
The Auto-Com now has an optional 30 character red LED (calculator type) display built into the laptray in addition to the miniature strip printer. This battery powered display provides better visual feedback to the user and a correctable output for short messages without compromising the portability of the Auto-Com. The 30 letter display is completely correctable, and when used with the strip printer, allows the user to correct any mistakes before the message is printed out.

Adaptable Pointing Area

A standard feature of the new Auto-Com allows the pattern of the vocabulary squares to be changed quickly and easily so that the squares may be placed in a pattern which is best suited to a particular individual. To change the pattern, the clear plastic top of the Auto-Com is lifted and a printed pattern of the desired vocabulary squares is positioned under the protective cover. A specially programmed matchbox sized memory module is then inserted into the aid to change the operation of the Auto-Com to match the new selection pattern. Three examples of selection patterns which would be possible with this feature are shown below:


Standard Rectangular Pattern


Pattern For Child Who Cannot Cross Midline


Pattern For Use With Headstick

Expanded Wordmaster

The standard Wordmaster feature allows the Auto-Com to print words, phrases, and sentences as well as single characters. This vocabulary is stored in miniature memory modules which may easily be inserted into or removed from the aid. Vocabulary words and phrases may be added or changed by simply exchanging memory modules. By increasing the number of modules used in the aid, the Wordmaster vocabulary may be expanded up to approximately 750 words.

An optional addition to the Wordmaster allows up to approximately 32 words to be changed or added to the Wordmaster vocabulary by operating directly from the top of the Auto-Com. The vocabulary thus may be changed by the child or another person on a day-to-day or hour-to-hour basis, since no memory module exchange is necessary.

February, 1976

APPENDIX B

LANGUAGE SAMPLES

LANGUAGE SAMPLE
SCC

S: "What did you do last night?"
I com from school and I aet stad.
T: I come from school and I eat steak.

S: "Tell us about the filmstrip 'Work of Flowers'."
Sow flowers for can see plainn.
T: Sun flowers, for you can see them plainly.

S: "What did you do last night?"
I com and aet arie whoch NT.
T: I come home and ate and watched TV.

S: "Tell us about Miss Pickerel."
Miss Pickerel is like all gramom.

S: "Tell us about the breakfast you had."
Is it good and have pig (pork sausage) and fau toast.
T: It was good and I had pork sausage and French toast.

S: "Tell us about the park cleanup."
Me and Jim now the bracke up.
T: Me and Jim mowed the park up.

S: "What did you do last night?"
I caom home ane I aet pig (pork).
T: I came home and I ate pork.

S: "What did you think of the new baby?"
Mr. Caswell is not look hem because eaey red.
T: Mr. Caswell does not look like him because his eyes are red.

S: "What did you think of the fire drill?"
What good and Jills mouth go saw on.
T: It was good because Jill had to shut her mouth.

S: "Tell us anything you like."
I my hot go in both and coold pies and whot TV.
T: I am hot and would like to take a bath and have a pop with a piece of ice and watch TV.

S: "Why were you absent yesterday?"
I rove speep to Tam and whoch TV.
T: I overslept to Tam and watched TV.

S: "Describe a favorite TV show."
The Winas garpop becoll have moon from.
T: The Walton family.

S: "Describe your impression of today."
I tist caut com was good.
T: I tested on the Autocom, it was good.

S: "What did you do last night?"
I went home and eat supper.

S: "Tell me what songs you sang in music and what you did."
I saing Jom giri and the 8 brat.
T: I sang Georgie Girl and the 8 part round.

S: "What did you do during the hobby club."
* I watched the card players.

S: "What did you do over the weekend?"
I mov in nout hout.
T: I moved in a new house.

S: "What did you do in gym today?"
I watched the praeling on the roup.
T: I watched them crawling on the rope.

S: "What did you have for lunch today?"
I had a mache and Harriett and a backe.
T: I had a sandwich, chicken delight and a bag cf onion flavored corn curls.

S: "What did you do last night?
I eat stad and whot the flid of what qs.
T: I ate steak and watched TV, "The Flight of the White Geese."

S: " What did you have for lunch?"
My have think.
T: May I have a drink.

S: "What are you going to do this weekend?"
I will go to bar.

S: "Tell the group something."
Man is red and balck and want the red is hurt.
T: Man is red and black and wanting. The red man is hurt.

S: "How do you feel?"
I am hot and hot of head.
T: He is saying he has a fever.

S: "What did you do on memorial day?"
I go picnicing and fishing.

S: "What do you like to drink?"
I like pise.
T: I like pepsi.

S: "Tell us about the weather."
It is suna and clod.
T: It is sunny and cold.

S: "What did you do this weekend?"
I whoert on bout.
T: I went on the boat.

S: "What is your group planning for a poster?"
The on byy beaal bck anda.
T: The boy on the bicycle.

S: "Tell us about the picnic."
It is good and the fight.
T: He and Steve wrestled.

S: "Tell us about yesterday's Olympics."
It is good and Macke sow for Mr.
T: uninterpretable

S: "What did you do last night?"
I whot can in and hurt Bob.
T: I watched Cannon and hurt Bob.

S: "Write about our film festival."
Mr. C. and Ms. S. saw in the move.
T: Mr. C. and Mrs. S. were in the movie.

S; "What did you do last night?"
I whent to the whaing.
T: I went to the wedding.

S; "What did you do this summer?"
I tow in the baot.
T: I rode in the boat.

S: "Tell us about today's gym."
It is good and the Mr. Caswell and low 19 to 20.
T: It is good and Mr. Caswell was low score 19 to 20 (The teachers were playing against the children).

S: "Tell us something about your new house."
Have is a TV and clan.
T: We have a TV and it's cable.

S: "What did you do during lunch hour?"
* I like to Pat and Eric Chase.

S: "Tell us about gym today."
The holde try all try up there Christ at Mr. Caswell and Mrs. De.
T: The older team try and try to beat the children.

S: "What did you do?"
I paly Bingo and did won.
T: I played Bingo and won.

S: "What do you think of Ford pardoning Nixon?"
Nixon is go nut.
T: Nixon is going to go insane.

S: "Tell us about jelly making."
It is good and Mr. Caswell behame nut.
T: It is good and Mr. Caswell behaved nutty.

S: "Tell about the canning of tomatoes."
It is some Mr. Caswell blude red.
T: It is the same as Mr. Caswell, blood red.

S: "How did we can pickles yesterday?"
Go and whos the jrims and whos plick pot in jrim.
T: Go and wash the jars and wash the pickles. Put the pickles in a jar.

S: "How are you feeling today?"
I come home and eat whot TV bed 365 days nuts.
T: I come home and eat and watch TV 365 days a year - nuts!!!

WORD USAGE ANALYSIS - IRREGULAR WORDS

SCC

SCC Word	Meaning	Usage	Frequency
1. com	come	v	3
2. sow flowers	sun flowers	n	
3. aet	ate	v	5
4. whoch	watched	v	6
5. gramom	grandmother	n	
6. ane, aynd	and	c	5
7. fau toast	French toast	adj	
8. bracke	raked	v	
9. caom	come	v	
10. from	form	v	
11. eaey	eyes	n	
12. coold, clod	cold	adj	
13. pies	piece	adj	
14. whot, whosh	watch	v	4
15. rove speep	overslept	v	
16. Winans garpop	Walton family	n	
17. becoll	because	conj.	
18. tist	test	v	
19. caut com	Autocom	n	
20. pace	played	v	
21. backeball, bickball	basketball	n	6
22. heaed	hurry		
23. nout	new	adj	
24. hout, hos	house	n	
25. praeling	crawling	v	
26. roup	rope	n	
27. mache	sandwich	n	
28. backe	bag	n	
29. flid	flight	n	
30. stad	steak	n	
31. ead	eat	v	
32. balck	black	adj	
33. sore	sorry		
34. somtam	sometime		
35. docke	desk		
36. and one	anyone	copied as spelling words	
37. juch	large		
38. thoun	those		
39. bruane	number		
40. baech	beach		
41. faring	finger		
42. plae	people		
43. blit	bottle		
44. blud	build		
45. frice	fence		
46. croun	corner		
47. whill	wheel		
48. fad	knife		

SCC Word	Meaning	Usage	Frequency
49. cloce	clothes	copied as spelling words	
50. aro	arrow		
51. cout	quick		
52. whan	women		
53. fivey	fifty		
54. bracke	break		
55. pisc	pepsi	n	4
56. Kama	K Mart	n	
57. Thety	french fries	n	
58. beet	beef	n	
59. suna	sunny	adj	
60. whoert	went	v	
61. bout, baot	boat	n	
62. beaalbckanda	bicycle	n	
63. teab	table	n	
64. fraeld	funny	adj	
65. stin	sign	n	
66. fatherball brothball	football	n	4
67. move	movie, film	n	
68. saw	was, were	v	
69. whaing	wedding	n (do)	
70. brack	park	do	
71. frost	first	adj	
72. poap	potato	n	
73. conio	corn	n	
74. clap	cable (TV)	adj	
75. all a pot	all about		
76. holde	older	adj	
77. Frather	father	n	
78. paly	play	v	6
79. be ham	behave	v	
80. haint	hit	do	
81. blude	blood		
82. Doag	Doug		
83. whos	wash	v	4
84. jrims	jar	n	3
85. plick	pickle	n	
86. pot	put	v	
87. ylo	yellow	adj	
88. thaesh	teacher	n (do)	3
89. lacke	look	adv	
90. hud	hunting	v	
91. braed	bear	n	
92. all raet	alright		
93. wat	went	v	
94. smow	soup	n	
95. Pbote	Peabody	n	
96. popat	potato	n	
97. met	meat	n	
98. caow	corn	n	
99 tow	rode	v	

LANGUAGE SAMPLE
SDC
April, 1973
(Prior to Use of Autocom)

1. Gregg phoned Miss O'Connor about the talking board.
2. At first he said I could have the board at the end of the week.
3. Then he decided no because there was no top on the letters.
4. He talked a long time to Miss O'Connor.
5. She will come and see me often during the summer to see how I am doing.
6. He was very busy.
7. Some people there.
8. He had to show them what they were doing.
9. I am tired.
10. Can you pick up John tomorrow?
11. We may have no school on Mon.
12. We will go, but people will come there and we will come home.
13. I can do more things by myself.
14. I can write my ideas down right away.
15. People will not wait to learn how to talk to me now.
16. My hands are hard to see when they (people) do not know how I point.
17. I think the letters will help people talk to me more.
18. I will write letters.
19. I will write answers and stories.
20. Maybe I can use it for a job.

LANGUAGE SAMPLE
SDC
May, 1974

1. Bob is a toad.
2. My name is Diana Creer.
3. You have to make drinks for math.
4. I think people talk to me more than befor.
5. I have a exam in Algebra on friday.
6. I started to write my report.
7. I like to see what I pleas see.
8. I decide that I like it.
9. I am good.
10. He is not going today.
11. I find that CR do not work with this.
12. I prepared 2 to be involved.
13. This sound wrong.
14. They marry inside the group.
15. This is very haked, working without T.V.
16. I think I see it.
17. Gregg, I have to remember what I said what I doing.
18. Is years ago my parents had problem to fine school for me.
19. Is not any classes for me then.
20. When people saw me the first time they do not know how to act for me.
21. Some of people think that I'm dumb or deaf because I am not talk.
22. They thought I'm mentally retarded because I'm not talk.
23. They tredat me like I'm little.
24. People ask me silly question.
25. They do not know I think too.

26. I like to useing this on T.V.
27. I am making this on word board.
28. I like to be useing this.
29. I have 2 kinds CP.
30. I looking for house for handicapped persons.
31. How can I see?
32. It is very hard for me to see.
33. I can not see what I'm doing.
34. I think that this is much better to talk with people.
35. Thanks to comeing.
36. I want to eat now.
37. Today Debbi and Dick came down to give me some test.
38. They aren hard for me.
39. I'm going to camp on June 23.
40. Please come to see me.
41. Say hi to your sister for me tomorrow.
42. I wish Judy get up soon because I want to go outside.
43. I write him to tell about this.
44. I like it.
45. Do you like it?
46. Tomorrow I woulde to write a letter.
47. I think so.
48. I want to have somebody over the weekend.
49. Oh! I want to go to Kmart with you.
50. I want to get shol.
51. We want to talk to you please.

LANGUAGE SAMPLE

SLS
December, 1972
(Prior to Use of Autocom)

1. What book am I getting next?
2. Can I see it?
3. I watched the movie of the week.
4. We were at the farm.
5. 1969 we move in March.
6. Dad was on the farm 30 years.
7. Boy oh boy thats a sad plase.
8. I got good idea.
9. Go over to M.P.'s to play on the rug.
10. Are we going?
11. I can belev him like a rock.
12. Mrs. P. is going to move.
13. Can Mark go to speech?
14. I like to know what is going on.
15. I good a good idea.
16. Go P.T. with Pete.
17. Can I?
18. I wish I could ben hear the day.
19. I heard that Kit is leving friday.
20. I was thinking I would go up to the imc and get some records.
21. What happining if I don't have time?
22. When is fun day?
23. Don't you plan any work fri.
24. I get sick of the cold.

25. I knew about that.

26. Play in the snow.

27. It's boaring.

28. Sandy and Ron got annew dog.

29. I hate this naw (new) time.

30. It is dake (dark) 4:03 (4:30).

31. Sandy got rid of Buffy because she was sick.

32. Dad said keep her in the barn.

33. I was mad Sat.

34. That ather (other) mut (mutt) sough (should) got rid.

35. I'd like to kill.

36. That dog bites.

37. He bit Kelly and Kim.

38. My box is done.

39. I am mack (make) it for the fun of it.

40. I just have the lock.

41. We are in for bad time.

42. What are thouse (those) for?

43. I don't get it.

44. Forget it.

45. You blap (blab) it around aniaway (anyway).

46. I hope that box will be ok tonight.

47. I am afraid won't get a 100.

48. What is going on.

49. Mad he talk too muh.

50. I like you too.

51. I have am.

52. I show Kelli to smart for her.

LANGUAGE SAMPLE
SLS
May, 1974

1. School is a building.
2. I live in a house.
3. I go to the store.
4. I won't come back after fun day.
5. 2 days of school, Monday and Tuesday.
6. Hospital is a building and school is too.
7. Remember our talk with Mom.
8. I went to the farm with Ron and Dad picked me up there.
9. I want you to come down this summer on a sunday like you did last year.
10. Can you do it?
11. I want you to.
12. Pick a date after camp.
13. Where is my old board?
14. I want xetra.
15. I'm getting sick of waiting and Mr. Wendt is too.
16. Get it here or else.
17. There is taxi in Monroe.
18. I think I will not take it home tonighth (tonight).
19. I got to use it.
20. I'm happy.
21. I don't get you.
22. Sandy use it.
23. I give it to Dad.
24. Why are you leaving?

25. I talked a lot.
26. Will I be here next year?
27. Can we bring sack lunches on fun day?
28. I want to give you a demonstration tomorrow.
29. I wish I could write my book.
30. We have got 14 days left.
31. I will glad when this year is over.
32. What do you mean?
33. Lets make a deal if hurt on friday.
34. I'm sorry Pat.
35. You could bring your one (own) if you wanted.
36. I'm going to Gompers.
37. Are you going to Camp.
38. I wish I could go to speech.
39. I like the rooms without windos.
40. More I could bring lets talk tomorrow.
41. You have the last kiss.
42 I don't see why not.
43. Why won't you take me dancing?
44. I want to give that to him.
45. Mom, when are we going to mark and pack.
46. We better get going.
47. I remember going with my Dad.
48. He used to take me night.
49. Sometimes we used to go on Sunday.
50. We used to go shoping.
51. I'm going to Jr. High.

APPENDIX C

DATALOGGER INFORMATION

DATARECORDING AIDS

What is the Trace Datarecorder?

The Trace Datarecorder is a sub-miniature cassette tape recorder which fits into a special cartridge. This cartridge then slips into the upper right hand corner of the Autocom (Figures 1 and 2).

What does it do?

The Datarecorder will record in digital form all the messages which are printed on the Autocom. In addition to recording all of the output from the aid, the Datarecorder will automatically mark off one-minute time segments on the tape to aid in taking time samples and establishing time of day.

Why is it needed?

One of our major concerns right now is studying language development processes in non-vocal motorically impaired children. For this we need accurate information on what the children say, or produce, and the context and manner in which they say it. We tried to obtain this information from the thermal print tape, but it wasn't accurate enough as we could not tell what transpired prior to the outprint of the message (i.e., we couldn't tell which mistakes had been corrected).

The Datarecorders were developed so that we could obtain much more detailed information without necessitating laborious teacher-written language samples.

What information can be obtained from the Datarecorders?

All of the Datarecorder information will be logged on a sub-miniature tape cassette. This tape will then be fed into a computer which will analyze and reconstruct the information for us.

Because every minute will be "marked off" on the tape, we will be able to combine any number of these minutes into time samples (similar to the five-minute samples we collected previously in our pilot studies). In addition to time sampling information, we can obtain the following:

1) vocabulary and word frequency counts
2) grammatical usage frequency
3) amount of time needed to construct the message
4) number of errors in the message
5) number of corrections made in the message
6) tally of spelling errors
7) number of unique words printed
8) average number of words in sentences
9) average number of letters in words

INSERTION OF DATARECORDER
INTO COMMUNICATION AID

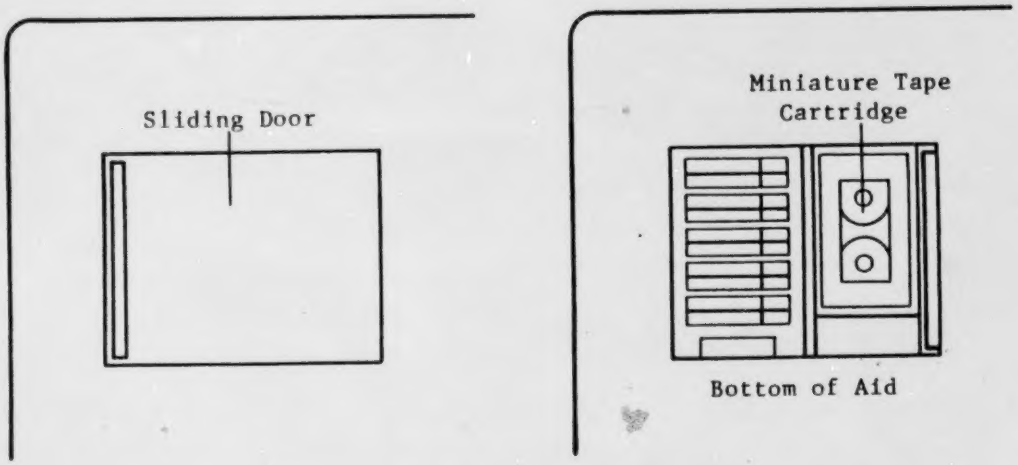

Sliding Door
Miniature Tape
Cartridge
Bottom of Aid

FIGURE 2

These are a few examples of information which we can obtain. All of this information is crucial to the study of language development in non-vocal children.

What if the student doesn't want us to know what he is saying?

The Datarecorder can be "turned off" at any time, and the student can delete certain messages from the transcript. To turn the Datarecorder on and off, a code is printed before and after the "private" message.

CODE = [[. . . . .]]

Example: message to be deleted = I love you

[[I love you]]

What do I (as a teacher or parent) need to do?

Every two weeks the Datarecorder tapes (inside the cartridges) must be changed. We will supply the tapes for you. Steps for changing the tapes are:

1) Open sliding door

2) Remove tape cassette

3) Date the tape and label with the student's name.

4) Date the new tape and insert it into the aid. (Push firmly when inserting the tape).

5) Close sliding door.

6) Send the dated and labeled tape back to Trace Center.

If you have questions or problems at any time, please don't hesitate to call Deb Vanderheiden at (608) 262-6966.

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